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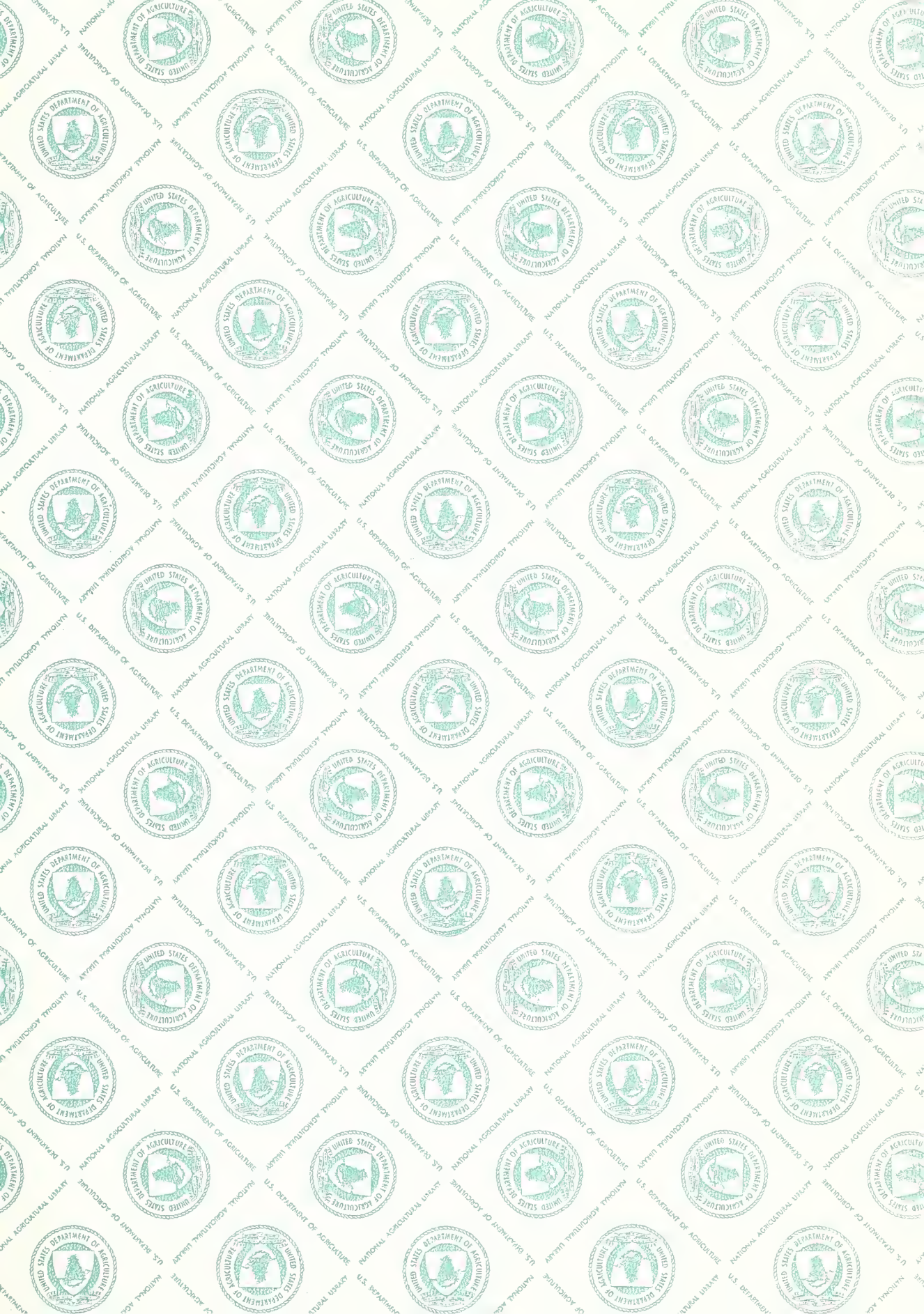














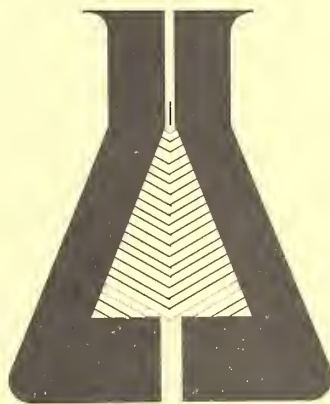
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# FOREST SERVICE RESEARCH ACCOMPLISHMENTS 1975

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## **ACKNOWLEDGEMENT**

The cooperation and assistance of the Forest Service research personnel is hereby gratefully acknowledged. This publication was partly produced through the Oak Ridge Computerized Hierarchical Information System (ORCHIS) at the Oak Ridge National Laboratory, Oak Ridge, TN.

UNITED STATES DEPARTMENT OF AGRICULTURE  
FOREST SERVICE

Washington, D. C. 20250

1380(4000)



Mr. Robert W. Long  
Assistant Secretary  
U.S. Department of Agriculture  
Washington, D. C. 20250

Dear Secretary Long:

I am pleased to send you the report on Forest Service Research Accomplishments for 1975.

This report presents an overview of Forest Service research achievements and a comprehensive list of publications. It reflects the emphasis of a research program directed at solving the multifaceted problems of managing our Nation's renewable natural resources.

The new technology reported here will be useful to other scientists and to practitioners in Federal, state and private employment. The Forest Service is strengthening its efforts to assure that this technology is quickly transferred to and utilized by those who need it.

Sincerely,

A handwritten signature in dark ink, reading "John R. McGuire". The signature is fluid and cursive, with the first letters of each word being capitalized and prominent.

JOHN R. MCGUIRE  
Chief



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U.S. DEPARTMENT OF AGRICULTURE

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## FOREWORD

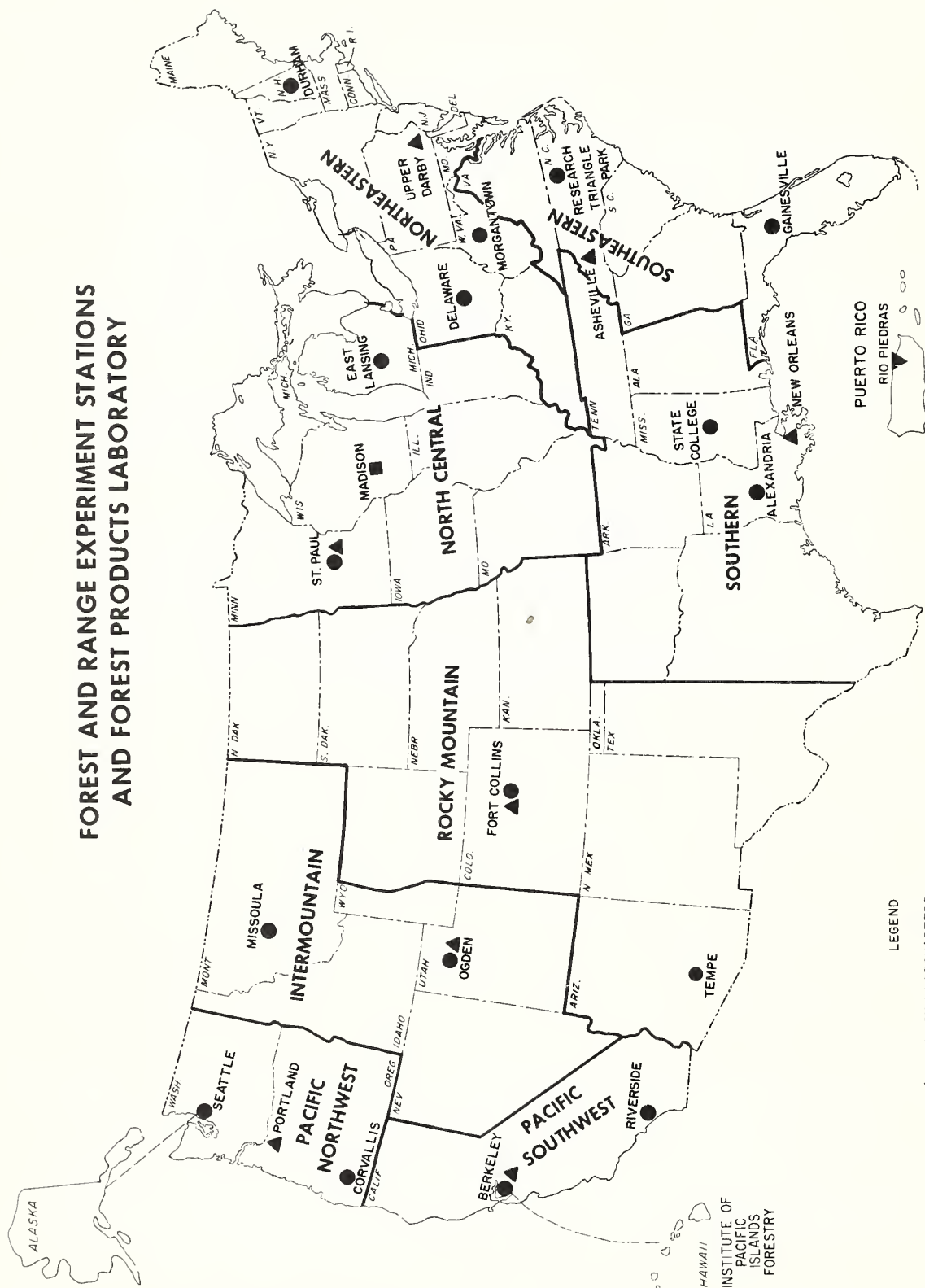
Forest Service research plans are coordinated through the Assistant Secretary for Conservation, Research, and Education with research in other USDA agencies, as well as that conducted under the Hatch Act at land grant institutions, and under the McIntire-Stennis Act at schools of forestry.

Development and coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies are accomplished through the Regional and National Agricultural Research Planning Program directed by the Agricultural Research Policy Advisory Committee and the National Planning Committee.

Coordination is also maintained through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements providing for joint development and support of the research by the cooperators.

This report is arranged by research subject areas as a convenience to the reader. Each accomplishment is summarized in a single, short paragraph. Numbers in parentheses following the paragraph indicate relevant documents in the Publications List. Following each paragraph and publication citation is an abbreviation indicating the Forest Service research unit best able to supply detailed information and copies of the publication. Abbreviations and addresses of the research units are given on the following page.

# FOREST AND RANGE EXPERIMENT STATIONS AND FOREST PRODUCTS LABORATORY



## LEGEND

- ▲ STATION HEADQUARTERS
- ASSISTANT STATION DIRECTOR LOCATION
- FOREST PRODUCTS LABORATORY
- ▼ INSTITUTE OF TROPICAL FORESTRY

INSTITUTE OF TROPICAL FORESTRY  
PUERTO RICO AND U S VIRGIN ISLANDS

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Fort Collins, Colorado 80521

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Southeastern Forest Experiment Station  
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Agricultural Experiment Station Grounds  
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## WO

Deputy Chief for Research  
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Washington, D.C. 20250

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# IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS

## Reducing Pollution

### Controlling soil erosion

1. Surface erosion from road construction, mining, and the like, may create serious impacts on fish habitat and other watershed values. A model for predicting surface erosion in the Idaho Batholith indicates that surface erosion is highest immediately after disturbance and decreases rapidly over time. Increased stoniness of the ground surface (erosion pavement) appears to be the dominant factor causing the trend. Mulching, netting, and transplanting can reduce soil losses during the period before seeded vegetation becomes established. —INT(10).

2. Ponderosa pine is well suited for stabilization of road fills in the Idaho Batholith. Ninety-seven percent of the trees planted survived. Growth was increased 95 percent by fertilization. Erosion was reduced 32 to 95 percent, depending on whether straw mulch and netting were used in combination with tree planting. —INT(11).

3. Most eroded areas of the southern Coastal Plain can be successfully stabilized by bar-planting loblolly pine, but some sites defy repeated efforts. Statistical analysis of the chemical and physical characteristics of soil were used to detect hard-to-plant areas. Bulk density was the most important variable as it alone correctly predicted the success or failure for 78 percent of the sites. Where densities exceed 1.45 g/cm<sup>3</sup>, alternate planting methods are required. —SO(7).

4. Lovegrass planted and fertilized to quickly protect a site may overwhelm pine seedlings and thus prevent permanent control of erosion. This problem was solved on sandy soils in northern Mississippi by delaying application of two-thirds of the required fertilizer until late July. The delay boosted pine survival from 33 percent to 73 percent—a rate near that of pines grown free of grass competition. The results demonstrate that combined plantings are feasible for both rapid and long-term site protection if competition between species is controlled. —SO(6).

5. Major highway construction is under stringent regulation in subarctic Alaska, but pioneer type access roads have been neglected. These smaller roads are often erosion hazards and may contribute to fire and insect problems. Guidelines for development of roads in the subarctic have been designed for road builders with limited engineering and planning staffs. They are based on Federal and State environmental regulations for the conterminous United States modified by local experience in subarctic conditions. —PNW(106).

6. Mass soil movements reduce site productivity by removing soil material and lowering nutrient capital available for plant growth, and they introduce significant quantities of sediment into forest streams. Natural mass movements on forested slopes in the western United States can be divided into two major groups, (1) debris movement and (2) soil mantle movement. Steep slopes, high soil moisture, and periods of abnormally high rainfall are commonly associated with move-

ment. Logging operations can be major contributors to this process. Future land management operations can influence or be influenced by soil mass movements. —PNW(131).

7. Landsliding in steep glaciated terrain of southeast Alaska is a serious problem for forest land managers. Soil mass movements are the dominant erosion process on the steep forested slopes. Effective management of such terrain consists of identification and avoidance of the most unstable areas and careful control of timber harvesting operations in questionable zones. —PNW(132).

8. One of the more visible and controversial environmental impacts associated with timber harvesting in subalpine coniferous forests is road building. A preliminary model has been developed for predicting an index of onsite erosion and downstream sediment yield. By describing the disturbed area in terms of watershed slope and engineering design, the land manager is provided some flexibility in evaluating the impacts of various road systems in the central Rocky Mountains. —RM(9).

9. Field survey and design procedures conventionally employed for control of gullies on forests and rangelands require relatively high expenditures of time and money. Design of gully control with check dams has been computerized and made operational for field use. The computer program requires a minimum of data to generate designs and to furnish critical information concerning materials and costs for alternative designs. This procedure can facilitate inventory of needs for gully control and the selection of treatments where control is necessary. —RM(8).

### Chemicals in the forest environment

10. TCDD, a contaminant of commercially produced 2,4,5-T, may enter forest streams with the herbicide during aerial application on forest land. Exposure of guppies to 0.1, 1.0, and 10.0 ppb TCDD for 120 hours caused complete mortality in the next 32, 21, and 30 days, respectively. Duration of survival was significantly and positively correlated with body length. Concentrations of TCDD used in the tests were significantly greater than expected to occur in forest streams after aerial application of 2,4,5-T. —PNW(22).

11. Cacodylic acid and MSMA (arsenical silvicides) are used in precommercial thinning of Pacific Northwest forests, but their impact on soil microorganisms is not known. Both chemicals inhibited the growth of four bacteria in liquid culture at 1000 ppm but not at 100 ppm. Concentrations of less than 10 ppm arsenic had no significant effect on decomposition of organic matter. Neither chemical will seriously affect forest microbial populations, their decomposition of organic matter, or other functions important in the maintenance of soil fertility. —PNW(13).

12. There is concern that the use of endrin on forest tree seeds may introduce significant quantities of the chemical to the aquatic environment. Following aerial seeding of two western Oregon watersheds with treated Douglas-fir seed, detectable residues of endrin were found in a steep gradient

stream for a period of less than 5 hours and in a slower flowing stream for 11 days. Maximum concentrations were well below 96-hour median tolerance limits for important fish species. —PNW(17).

13. An understanding of the behavior of pesticides in plants is necessary to accurately evaluate the consequences of pesticide usage in the forest. Chemical and physical properties of a pesticide and interacting environmental factors determine the movement, persistence, and fate of pesticides in plants. The behavior of a pesticide determines its field effectiveness and its residue characteristics. —PNW(19).

14. Salt (NaCl) used to deice highways has injured roadside trees in the Lake Tahoe Basin of California. In 1 year, an estimated 3,000 trees were damaged or killed on 321 sites. Symptoms and concentration of salt in the needles of exposed trees were determined and described. Results will help the State Division of Highways develop environmental impact statements and indicate the need for additional studies in the area. —PSW(440).

15. Although mirex has been the standard insecticide for control of the imported fire ant in the southern United States since 1963, relatively little is known about the interaction of this insecticide with soil microorganisms. Field and laboratory studies show that mirex is not degraded by and appears to be innocuous to soil microorganisms. Mirex remains in unconsumed bait but becomes slowly incorporated into the soil as the bait decomposes. It does not leach into ground water, but it is probably washed into streams and lakes by surface runoff. This information will provide some of the basis for evaluating current and future use of this insecticide. —SE(15).

#### Air pollution

16. Injury of ponderosa and sugar pine caused by air pollution is significant in southern California, but guidelines for distinguishing this damage from other common foliage problems have been lacking. Changes in needles of ponderosa pine caused by ozone ( $O_3$ ) and sulfur dioxide ( $SO_2$ ) singly and in combination were delineated microscopically and contrasted with winter fleck injuries. The ability to identify air pollution damage in the western United States will permit scientists and researchers to develop better management and control recommendations for minimizing the effects of air pollution. —PSW(536,539).

17. As urbanization and industrialization intensify, harmful gaseous and particulate emissions will adversely affect forest, nursery, and ornamental plantings. Nature, extent, and severity of ambient pollutants on coniferous and deciduous forests and seedlings have been described. This information will give nursery managers and foresters in the United States a better understanding of the causes and effects of air pollution, and enable them to develop improved management plans to minimize future losses. —NE(534,535).

18. To accurately evaluate air pollution resistance in trees requires long-term exposure to chronic low levels of pollutants. An attempt was made to develop a technique for shortening the evaluation time by correlating the response of plants to high and low levels of ozone. Fumigation of hybrid poplar clones with 15 ppm ( $O_3$ ) for 6 weeks caused a 50 percent growth loss and injured 75 percent of the foliage, but exposure of the same clones to 100 ppm for 2, 4, or 8 hours did not suppress growth though 70 percent of the leaves were injured. Lack of correlation between these treatments means nurserymen, tree breeders, and geneticists cannot use short-term, high-concentration tests to predict pollution tolerance in trees. —NE(538).

19. If toxicants were not removed from the atmosphere, air pollution would rapidly increase. Biological systems, e.g., forests, undoubtedly remove some, but which ones and how much are not known. Eastern American hardwood seedlings rapidly absorbed sulfur dioxide ( $SO_2$ ) and moved this chemical from leaves to roots. Thus, plant species with long-term  $SO_2$  absorption capacity may serve as sinks in locations where chronic pollution occurs. If confirmed, this information will be valuable to land managers throughout the country who will need to select species for future reforestation. —NE(537).

20. Air pollution damage to shade trees is widespread and of increasing economic and biological importance. Effort is currently being made to produce a tree with greater adaptability to eastern and midwestern urban environments. Tests with red maple indicate that seedling response to ozone exposure is genetically controlled. Through breeding and selection, urban foresters and geneticists may be able to develop red maple with increased ozone tolerance. —NE(540).

21. The sensitivity of trees to air pollution can be affected by many factors, such as nutrient levels in the soil. A greenhouse study in North Carolina showed that nitrogen fertilization significantly increased needle tip necrosis when potted propagules of a clone of eastern white pine were exposed to ambient air pollution. Conversely, phosphorus fertilization significantly reduced average needle injury and the number of affected needles over the entire tree. Further studies are obviously needed, but these results suggest that pollution damage might possibly be diminished by selected fertilization. —SE(662).

#### Recycling wastes--sewage effluent, sludge, and residues

22. Forests are potential sites for treatment and disposal of sewage wastes, but overirrigation with sewage effluent could result in excess moisture and nutrients. After effluent irrigation, a 20-year old stand of red pine and young deciduous and conifer seedlings on a sandy site in southern Michigan showed improved growth and survival of most species. Boron toxicity symptoms were indicated in the red pine needles. One to 2-inch irrigation treatments at this site appear to be environmentally acceptable. —NC(25).

23. Treatment and disposal of sewage wastes from forest campgrounds has been a difficult problem for land managers. Wastes from sewage vaults were injected into a sandy soil site on the Hiawatha National Forest in upper Michigan. Tests for bacteria and chemicals indicate on-site soil treatment protected the surrounding soil and water resources. With proper site selection, soil incorporation provides cheap, effective, and safe treatment of sewage from remote campgrounds. —NC(24).

24. Sewage effluents and sludges from municipal and industrial sources provide potential water and nutrient sources for intensive culture of forest crops. Pulp and paper mills may soon be required to use land renovation to meet effluent discharge standards. Intensive-culture forestry offers the only wetland management alternative that gives adequate nutrient uptake to provide long-term renovation of wastewater. Nitrogen enrichment of groundwater may be the controlling factor in such practices. —NC(26).

25. Management of forest residues may impact soil microbes important in the maintenance of soil fertility. Interactions between soil microbes and forest residues are controlled by six environmental factors which are drastically affected by burning. Microbial decomposition of forest residues recycles nitrogen and can improve soil physical properties. Microbial activity can be enhanced by reducing particle size of



residues, by providing good contact between residue fragments and soil, and by adding nitrogen to the site. —PNW(23).

## Improving Wildlife, Range, and Fisheries Habitat

### Characteristics and values of plants for food and cover

26. Bitterbrush is an important livestock and wildlife food in central Oregon. However, little is known about the impact of logging and slash disposal on bitterbrush. On a forested site, logging destroyed 71.5 percent of the bitterbrush crown area. Forage production recovered in 5 years after logging and continued to increase for 12-15 years. Disposal of slash was the primary cause of soil disturbance and reduction in shrub cover. Production of forage for livestock, deer and elk improved for 15 years. These results were used in establishing guidelines for coordinated management of timber and wildlife habitat. —PNW(161).

27. Information about seed is essential for producing shrubs to improve habitat for wildlife, furnish forage for livestock and protect soil from erosion by wind and water. Successful restoration of shrublands is dependent upon a basic understanding of the biology of native plants. Biological information about many shrubs on forest and rangelands has been summarized. Flowering and fruiting characteristics, seed collection, storage practices, and germination techniques are described. Land managers now have a current summary of the state of knowledge about shrub seeds. —PNW(186,188,190).

28. Short-hair sedge vegetation in the high Sierra Nevada of California is susceptible to abuse, and its rate of recovery is slow. The condition of vegetation was compared at several locations. Overuse was destroying short-hair sedge vegetation, leaving patches of bare ground. The rate of recovery was extremely slow, requiring 70 years or more. These sensitive areas will require special attention to insure their continued productivity. —PSW(185).

29. In the eastern megalopolis, changes in land use are very rapid. Land use planners at town, county, and State levels need statistics, maps, and classification procedures to document changes in land use. To meet these needs in Massachusetts, a system for classifying land from aerial photographs and producing maps of areas as small as 3 acres was developed. Changes in vegetation and land use between 1951 and 1971 have been documented using this method. This system is an integral part of the effort to prepare a catalog of maps of Massachusetts useful to resource managers and planners in the future. —NE(167,168,169,170,171,173).

30. Land managers in the South need a better understanding of the geographic range of bluestem, an important forage plant for livestock and wildlife. Researchers found that separation of varieties of bluestem below the species level is impractical in management of southern range. Range management practices developed in one location are expected to produce similar responses in bluestem elsewhere. —SO(164,165).

31. Trees, shrubs, and woody vines constitute the major source of food and cover for wildlife in southern forests. One must be able to identify these important plants in order to evaluate habitat. The task is difficult, especially during the winter when the more recognizable plant features such as leaves, flowers, and fruits are often absent. A new publication describes and illustrates some key identification features of 70 species. It stresses the characteristics of stems and buds in winter, since a description of these parts is rarely available in

taxonomic references. As an aid in identification, species are grouped according to physical characters such as growth form (vines or shrubs), leaf, stem, and bud arrangement, and leaf persistence. This information will be useful to conservationists and land managers in identifying species for determination of wildlife habitat values. —SO(178).

32. Documenting use of habitat by animals is a most difficult problem. As a result of miniaturization of electronic components, radio transmitters can now be made for small animals such as the Abert squirrel. By radio tracking three squirrels in Arizona, it was found that each squirrel used from two to six nests in home ranges of 10 to 85 acres. Wildlife managers can use these data to develop criteria for evaluating habitat and to determine appropriate management units for Abert squirrel. —RM(179).

33. Ranchers in the Bighorn Mountains of Wyoming are interested in replacing big sagebrush with higher quality range plants. They need methods to control big sagebrush. In 1960 and 1961, big sagebrush (*Artemisia tridentata*) on four cattle ranges was sprayed with 2,4-D to improve livestock forage. By 1971, the canopy cover of big sagebrush was 8-42 percent of the pretreatment levels. Seedling density ranged from 5.7 to 11.3 plants/120 ft<sup>2</sup>. Herbage production was below the pretreatment levels with the proportion of graminoids about equal to that prior to spraying. Effects of deferment of grazing for as long as 3 years after spraying could not be detected. Increased herbage production after sagebrush control with 2,4-D was a short lived phenomenon lasting 3-5 years. —RM(192).

34. We need to know how and if low-resolution ERTS imagery can be used for inventory of natural renewable resources. Visual interpretation and machine processing of midsummer ERTS-1 imagery of a central Colorado mountainous area provided 85 percent accuracy for classifying conifer forests, deciduous forests, and grasslands. Classification for kind of forest, i.e., ponderosa pine, lodgepole pine, spruce/fir, Douglas-fir, and aspen, or grassland, i.e., bunchgrass or shortgrass, was not as successful. However, adjusting the apparent spectral signature of the ponderosa pine forest to account for slope differences improved classification by machine processing. ERTS type imagery would be useful for a first level stratification for inventories of renewable resources on a regional basis. —RM(160).

35. Improved grazing systems, based on the growth habits of forage plants, are needed to restore southwestern semidesert ranges to full production. The process of seed production in a perennial grass usually begins toward the latter part of the summer growing season, when microscopic changes occur in the growing point at the upper end of the shoot. At the time it changes from a vegetative to a reproductive condition, the growing point is probably less than 1/200-inch long. From this tiny beginning, the mature inflorescence rapidly develops. When grasses are in the early reproductive stage of development, a single bite by a rodent or a cow can remove not only the developing seed head but also prevent the development of a shoot and its associated leaves. On the other hand, if grasses are allowed to make substantial growth before they are grazed, fewer stems are needed to supply a cow's daily needs. —RM(157).

### Fish habitat resources

36. The herbicides 2,4-D and 2,4,5-T are used to control brush in Oregon and Alaska. Toxic contaminants from the herbicides may enter forest streams during spray operations. Researchers at Corvallis, Oreg. have determined levels of tox-

icity for several species of salmon and other aquatic organisms. This information helps resource managers predict the impacts of herbicides on aquatic organisms. —PNW(200,201).

### Wildlife habitat resources

37. Winter feeding is increasing the number and diversity of birds in and around suburban and metropolitan areas. In Amherst, Mass., 43 percent of the households queried fed wild birds during the winter months. The average household maintained 1.7 feeders and spent \$8.80 annually on bird food. The feeding of wild birds in suburban and metropolitan areas is a \$50 million a year industry. Wild bird feeding is important to a local economy and to songbird numbers, in addition to providing enjoyment to the public. —NE(206).

38. How can people and wildlife be brought together in an urban environment to provide maximum human benefit without destroying the wildlife? Wildlife biologists at Amherst proposed a strategy for managing wildlife in urban areas. Basically, wildlife management in cities must shift from pest control of rats, pigeons, and the like, to providing nongame wildlife solely for enjoyment. This analysis will be used to guide future research programs concerned with urban wildlife management. —NE(207,208).

39. Research in West Virginia suggests that songbirds can be concentrated in places where forest visitors can study, watch, and enjoy them. Songbird density and diversity in the Central Appalachians correspond to the kinds and quantity of shrubs in the understory. Requirements for nesting habitats of 31 species of birds have been summarized to guide management of songbirds. Managers in the southern Appalachians now have guidelines for managing habitats to increase forest visitor opportunities to see and enjoy songbirds. —NE(213).

40. DDT was sprayed on Oregon forests at the rate of 0.75 pounds per acre to control the Douglas-fir tussock moth. Researchers evaluated the short term DDT effects on survival of nestling songbirds and found no detrimental short term effects on mountain blue birds or house wrens. Nest boxes were placed in a spray and nonspray area to attract mountain blue birds and house wrens. The number of eggs laid and hatched and survival of nestlings were compared to determine the impacts of DDT. These results provide managers with some quantitative data on short term impacts of DDT on songbirds, but results should not be extrapolated to other species of insectivorous birds or to other habitat types. —PNW(239).

41. This state-of-the-art publication contains 34 separate papers ranging from philosophical aspects, problems with people-wildlife interactions, habitat requirements for urban wildlife, the role of the Federal and State governments in urban wildlife, to suggestions on management of people through education. The proceedings represent the first effort at summarizing the state of knowledge and are useful for planning and management of wildlife in urban environments. —NE(223).

42. To improve the quality of urban environments, many residents invite wildlife into their backyards. As the diversity of wildlife habitat increases, the chance of conflicts between man and wildlife also increases. Researchers in Massachusetts, stressing the need to become familiar with the animals' mode of life, compiled practical ideas and devices to minimize chances of conflicts. Using these suggested practices will help prevent conflicts with raccoons and skunks in your garbage can, squirrels in the attic, and chimney swifts in the chimney. This practical guide is useful for urban residents who share their backyards with wildlife. —NE(238).

43. Hunters and land managers in Florida are concerned about low deer populations in the Central flatwoods. Up to now, the causes have not been known. Recent research found that total numbers of deer in an area, variety of available food, and methods of hunting were not correlated with rate of reproduction. Deer reproduction was limited by low soil fertility resulting in food having a high lignin content and deficient in iron, copper and cobalt. Deer numbers can be increased by using one of several recommended methods to improve forage quality. —SE(216).

44. Clearcutting can adversely affect woodpeckers in southern Appalachian forests. Habitat preferences of four species of woodpeckers were identified and related to regrowth of forests following clearcutting. These data provide guidelines to land managers for maintaining woodpeckers in forest habitats. —SE(204).

45. Management of brood range of turkeys requires knowledge of the habits of free-ranging poults, but poults with hens are extremely difficult to observe in the wild. To overcome this problem, poults were imprinted to wildlife biologists. Human-imprinted turkeys make ideal research animals, whose behavior can be measured and used to define habitat needs. Use of imprinting-to-humans is not limited to precocial and ground dwelling birds. This approach should be useful in many studies of animal behavior and ecology. Information gathered by this method provides managers with the first quantitative information on habitats of turkey poults under near natural conditions. —NE(218).

46. Cutting ponderosa pine forests in Arizona is changing deer and elk habitat. Small, irregular, clearcut patches create diversity and provide large amounts of forage. Deer and elk benefit if there is adequate cover in scattered stands of saplings, poles, and sawtimber adjacent to the openings. Forest managers can improve deer and elk habitat by cutting one-sixth of a well stocked watershed in patches that range from a few to 32 acres. —RM(225).

47. Abert squirrels in Arizona clip twigs of ponderosa pine in winter to feed on the inner bark. The amount of food consumed can be estimated from a table that gives dry weight of the inner bark from dry weight of peeled twigs. A knowledge of the amounts and kinds of food consumed by the Abert squirrel helps ecologists understand one part of the nutrient cycle and energy flow in the ponderosa pine ecosystem. —RM(224).

48. High density of pocket gophers can cause serious damage to mountain rangelands. Therefore, it is necessary to monitor population fluctuations. Research in high mountain grasslands of Colorado shows that large-scale (1:1600) aerial photographs can be used for that purpose. Mounds of soil produced by gophers in late summer are highly correlated to population density. This method provides a more easily determined population density estimate and was found to be 97 percent as accurate as ground inventories. —RM(210).

49. The timber wolf is in danger of extinction in the contiguous 48 States. Up to now, little was known about physical parameters of pups in natural wolf populations. Pups with relative weights less than 65 percent of standard have a poor chance of survival, whereas pups of at least 80 percent of standard have a high survivability. Pups born in 1972 were equally underweight, probably as a result of declining white-tailed deer densities in the interior of the Superior National Forest study area. This information will contribute to the development of management guidelines to insure the survival of this important animal. —NC(241).



50. Accurately estimating animal populations from traps is difficult because probabilities of trapping young animals are lower than trapping adults. To correct for this bias, a weighting factor has been developed for cotton rats. The method used, based on trapping studies of a known population, appears universally applicable and should improve estimates of animal population trends and age structure. —INT(196).

### Rangeland management

51. High energy costs associated with production of feed grain and improved pastures are focusing attention on production of livestock on native range. Managers must recognize the limited quality of native forage species and use some supplemental feeds to boost the overall nutritional level in order to have a profitable livestock operation on southeastern ranges. There are 20.5 million acres of longleaf-slash pine-wiregrass ranges in the Southeast dominated by low quality shrubs or grasses. When grazing of native range is combined with improved forages, survival of calves increases 35-45 percent and weaning weights double. Range improvement through shrub control, fertilization, or plant conversion will greatly increase stocking capacity without excessive energy requirements. —SE(248,256,265).

52. Techniques for efficient inventory of multiple forest resources have been lacking. Researchers in Louisiana developed a procedure which was applied to forage resources for livestock and deer. A large-scale field test, encompassing nearly 7 million acres, demonstrated that comprehensive forest-range inventories can be conducted efficiently and at reasonable costs simultaneously with the nationwide Forest Survey. The procedure will assist in the assessments required by the Forest and Rangeland Renewable Resources Planning Act of 1974 (PL 93-378). —SO(263,838).

53. Livestock in southern pine forest-range require supplemental feeding. Researchers in Louisiana found that free-choice feeding of liquid supplements resulted in calf crops and weaning weights equal to or higher than those of cattle hand-fed cottonseed cake during winter. With liquid supplements during winter only, cows had lower production than either of the other alternatives. Net returns slightly favored the year-long, liquid supplements. These results provide cattlemen with methods for supplementing cattle diets on the South's native range. —SO(257).

54. Economic relief to cattlemen, substantial quantities of red meat for consumers, and conservation of energy can be obtained through judicious grazing of forest-range. Calves weaned from cows grazing forest range in central Louisiana sold at a \$10 profit, while those from improved pastures lost \$90 per weaning calf, mainly due to high feed and fertilizer costs. These comparisons provide cattlemen and landowners alternatives for more efficient and economical cattle production. —SO(262).

55. Research in Colorado resulted in a model of root dynamics in shortgrass prairie. Losses and replacements in roots are greater than previously reported. The model provides new insight into the effects of the environment and herbivores on roots. The shortgrass prairie is unique in that 60 percent of the plant roots occur in the top 10 cm of soil. Total root biomass remains constant, irrespective of grazing intensity. —INT(155,244).

56. Grass and brush increased when Idaho ranges were protected from livestock grazing. Surprisingly, this increase was very small. Because of the number of years required for significant recovery of vegetation, protection from livestock is not a feasible method to improve these ranges. Other manage-

ment practices are required to control sagebrush and increase grass. —INT(246).

57. Range managers often assume that the commonly-used measures of forage utilization reflect the amount of material actually consumed by livestock. However, considerable discrepancy often occurs between estimates of pounds of forage utilized and realistic appraisals of expected consumption. On native forb-grass summer ranges in southeastern Idaho and adjacent Montana, trampling accounted for 18 percent of the total standing crop "utilized" in pastures grazed by sheep in late summer, and 27 percent on open range grazed by herded sheep in late summer, and 18 percent on pastures grazed by cattle all summer. This study illustrates the magnitude of forage lost by trampling and indicates the need for quantification of trampling damage on many vegetation types and an evaluation of the physiological effects of trampling on individual plant species. —INT(250).

58. Forage and beef production on much semidesert grass-shrub can be increased by removing the shrubs mechanically. About 200 acres on the Santa Rita Experimental Range were chained in June 1970 to remove jumping cholla, staghorn cholla, pricklypear, velvet mesquite, and other shrubs. Mesquite on a second 200-acre area was killed with diesel oil. Recounts in 1974 showed that the density of staghorn cholla and jumping cholla on the chained area had been reduced to 2 percent and 6 percent of the original stand, respectively. Numbers of pricklypear in 1974 had been reduced only to 97 percent of the pre-chaining density. Chaining was very effective on mesquite. Compared to untreated range, grass herbage production in 1971 was 38 percent higher on the chained area and 76 percent higher on the mesquite-treated area. By 1974, once raw gullies on the chained area were lined with perennial grasses and several small head-cuts had healed. Control of shrub not only increases production of forage; it also helps to control erosion. —RM(254).

59. Yearlong grazing has been partly to blame for the poor condition of much semidesert range. Two alternatives to year-long grazing—rest each year from November through April, and rest each year May through October—were tested on the Santa Rita Experimental Range. Mesquite-free range produced 43 percent more perennial grass forage than mesquite-infested range and average utilization, greater than 40 percent, was consistently detrimental to perennial grasses during the 10-year study period. But perennial grass stands improved greatly in very favorable years and declined sharply in drought regardless of other conditions. Neither rest period proved superior to continuous yearlong grazing. —RM(252).

## Improving Social and Amenity Values

### Environmental amenities- landscapes and open space

60. Landscape planners need methods for predicting the impact of changes in land-use on esthetic quality. Landscapes vary considerably in their vulnerability and resistance to changes in land-use. A method is described for predicting vulnerability of landscapes and for ranking levels of vulnerability for some of the more sensitive aspects. Results are useful in setting priorities for development of landscapes and in the preparation of environmental impact statements. —PSW(270).

61. Because pictures of outdoor environments are used many different ways, resource planners, educators, advertising executives, and others are interested in knowing how effectively a photograph duplicates or changes public opinion or feeling about an actual scene. Overall results of a recent study indicated that if a photograph of an outdoor scene adequately

depicts most of the variety in a scene, respondents have similar reactions (in terms of the adjectives they use to describe both the photograph and the scene). The results reinforce inferences from previous research in which photographs were used to measure reaction to scenic quality. Photographs of landscapes can be used to measure public preference for scenic quality and to obtain valid viewer reactions to proposed resource management practices. —NE(271).

62. Guidelines are needed for reducing the impacts of debris resulting from timber harvest on lands that are also managed for recreational and esthetic values. Relevant information has been developed for planning, harvesting, and interpreting timber management activities to enhance scenic beauty and help forest visitors understand what they see. Management can apply these principles to improve satisfaction of recreation visitors in environments disturbed by logging slash. —PNW(272).

63. Landscape planners are continually searching for natural vegetation that will enhance the scenic quality of the environment. Because of its beauty and ability to survive in rugged terrain, the canyon (or big-toothed) maple seems to be a promising candidate for enhancement of recreational lands that surround lakes in the Intermountain region of the United States. However, rate of seed germination varies considerably among individual trees. Propagation procedures and the mechanism of seedling survival are being studied under natural conditions. Eventually, selections with outstanding merits may be released to nurseries for commercial production. —INT(269).

#### Environmental amenities--wilderness

64. When demand for a given recreation activity far exceeds supply, planners must decide if other recreation opportunities could be developed as substitutes. Current research suggests that substitutability among recreation areas and activities is suggestive rather than conclusive. It is important to recognize that use of wilderness, for example, may not be a substitutable recreation experience. —PNW(276).

65. The increasing demand for wilderness is the focal point of wilderness management problems. Results of all research done and sponsored by the Forest Service Wilderness Management Research Unit at Missoula, Montana, have been reviewed; and solutions to related management problems have been summarized. Topics covered include: the place of wild-fires in wilderness management, campsite and trail use, carrying capacity, user satisfaction, use measurements, wilderness permits, visitor characteristics, use simulators, and use distribution. This summary clarifies many of the challenges and issues of wilderness management. —INT(279).

66. To properly evaluate the feasibility of utilizing fire as a technique for managing vegetation in the interior-zone of the Boundary Waters Canoe Area, fire's historical role in the ecosystem needs to be understood. Research indicates that fire largely determined the composition and age structure of the area's forests; influenced nutrient cycles; and maintained the diversity, productivity, and long term stability of the area's ecosystem. The results of this research suggest that the use of fire is an ecologically viable approach to maintaining the natural ecosystem of this wilderness area. —NC(274).

67. To determine strategies for managing vegetation in the interior-zone of the Boundary Waters Canoe Area, knowledge of the composition, structure, and relationships of plant communities is needed. Ecological studies in the area indicate that the composition of plant communities is largely determined by: time since last disturbance, composition of the original commu-

nity that was disturbed, and the severity of that disturbance. Other environmental factors are less important because of the narrow range of climatic conditions and the broad range of plant tolerances in the area. With this knowledge, managers can develop appropriate strategies to reduce the detrimental impact of such disturbances. —NC(273).

68. Managers are vitally concerned about the impacts of recreational use on campsites. Thirty-three campsites in the Boundary Waters Canoe Area were studied for 5 years to determine the impacts of use on soils and vegetation. The effects of user impact tended to level off after the first 2 years. Results suggest that campsites should not be closed or campsite-use rotated in order to avoid user impacts. Criteria are provided for designing and locating campsites. These criteria consider the limitations of the environment and the types of people who use it. —NC(281).

69. Wilderness-use data can be tabulated in an infinite number of ways; some tabulations can be extremely valuable to managers. Analysis of data from user permits in the Boundary Waters Canoe Area shows how management can: understand trends or changes in use; determine where and when the regulation of visitors may or may not be necessary; select locations for public meetings and distributing news releases; and plan daily work schedules. The information presented underscores the importance of identifying summaries that are important for management purposes. —NC(277).

70. Because some wilderness visitors do not obtain permits, use estimates based on completed permit data need to be corrected. In a study of the Boundary Waters Canoe Area, 88 percent of the summer visitors sampled had a permit. Groups without permits were primarily daytime motorboaters. Reasons for noncompliance are not clear, but most of these parties probably were either unaware of the need for permits or did not entirely understand regulations of the area. By deriving expansion factors, based on the percent of groups without permits, total use can be estimated by multiplying the factor by the raw use totals. —NC(278).

71. Methods are generally inadequate for measuring how wilderness recreationists define a quality experience. A method has been described and tested for measuring recreationists' aspirations for, and perceptions of, conditions related to a wilderness experience. Comparison between aspirations and perceptions allow managers to identify specific sources of satisfactions and dissatisfactions associated with the experience, and to measure the relative contribution of each to overall satisfaction. The results are useful to managers because the elements evaluated by users are conditions that wilderness administrators can manage for—such as congestion, types of facilities, adequate maps, and fishing conditions. —NC(282).

72. To insure that wilderness management actions relate to public needs and values, comparisons need to be made periodically between the manager's and the user's feeling about wilderness values. Wilderness managers and summer canoeists were studied in the Boundary Waters Canoe Area to determine whether the two groups differed in their wilderness motivations, attitudes, preferences, and perceptions. Differences that exist suggest that management services will be less than optimal if the manager's decisions reflect his own attitudes and perceptions. —NC(283).

#### Managing recreational opportunities

73. Developers of commercial outdoor recreation enterprises and public park planners need factual information on trends in recreation participation. Analysis of 8 years of data on camp-



ing participation (reported by a panel of 459 camping families) revealed that: 51 percent of campers were either camping less or had dropped out of the camping market; campers increasing or decreasing their rate of participation were more likely to have experienced a change in their style of camping; and changes in camping style were either toward a more primitive type or toward season-long rentals and advance reservations at commercial campgrounds. Both trends in volume and style provide important clues for planning future facilities. —NE(302).

74. Potential developers of commercial campgrounds need to know what factors account for a successful recreation enterprise. Interviews of 529 commercial campground operators in 12 northeastern States indicated that success of an enterprise was strongly related to advertising expenditures. Operators who spent more than \$5 per campsite for advertising grossed an annual average of \$161 per campsite. Operators who spent less than \$5 per campsite advertising grossed an annual average of \$95 per campsite. These and other findings provide private investors with important information on campground development opportunities. —NE(288).

75. Managers frequently do not know how visitors react to actions designed to alleviate problems of overuse. Nonetheless, such reactions can play an important role in shaping management decisions in the future. A survey of skiers and hikers in the heavily used Tuckerman Ravine area of the White Mountain National Forest revealed that different user populations perceived overuse of the area in different ways. For example, spring hikers were less opposed to limiting visitor use than spring skiers or summer hikers. Both spring and summer visitors opposed more facility development, but recognized the need for more camping areas and better enforcement of user regulations. Results of the study influenced the management decision to use an overnight permit system to control overuse of the area. —NE(295).

76. If future recreation demands are to be met, management decisions must incorporate the opinions of a wide range of recreation-user groups. A survey of 157 campers and 281 boaters at the Allegheny reservoir on the Allegheny National Forest revealed that user and manager attitudes often were quite different. Furthermore, different kinds of users had different attitudes about: procedures to control recreation use, fee policies, zoning of recreational activities, procedures for law enforcement, and development of facilities. The study describes how to make recreation management decisions that minimize negative reactions from recreationists. —NE(304).

77. Better methods are needed to inform certain segments of the recreation public about rules and regulations. A survey of 588 campers on the Allegheny National Forest in Pennsylvania indicated that new campers, young campers, and campers not familiar with the camping area are particularly unaware of rules. Communications efforts directed to those specific groups will lead to a better informed camping public. —NE(306).

78. A democratic, technology-oriented society must anticipate and avoid changes that will detrimentally affect its basic life support systems of air, water, soil, flora, and fauna. Using the Delphi research technique, a panel of 900 experts provided forecasts of 125 future events about the Nation's natural environment. Events were grouped into five categories: natural resources management, wildland recreation management, environmental pollution, population-workforce-leisure, and urban environments. These perspectives on the future provide a basis for dealing more effectively with future environmental problems. —NE(307).

79. The ability to accommodate wildlife in the national economic system is one of the most significant challenges facing managers of natural resources. A recent survey indicated that wildlife values are emphasized only in situations where wildlife already exists in relative abundance. Forecasts of future wildlife priorities and benefits suggest that future demand for wildlife will involve non-consumptive benefits that accrue largely to urban populations. Results of this survey will help wildlife managers reorient programs to the changing needs of the American public. —NE(309).

80. Recreation resource managers and planners need a clearer understanding of how social factors and the physical features of the resource influence their decisions in urban, rural, and wildland management. Examination of the decision-making processes in four public land management agencies revealed that the highest priorities are given to elements that reflect immediate circumstances surrounding the decisions. Present recreation demand, available operating budget, and similar future recreation demand—in combination with physical characteristics of the resource base—were the major considerations. Results permit land managing executives to better understand how other agencies arrive at decisions on recreation management. —NE(308).

81. Increasing demands for fish and game call for more explicit management techniques in order to produce the experiences desired by sportsman. A "multiple-satisfaction approach" describes how to segregate a game management program according to the various kinds of experiences it provides. Using this technique, managers can appraise the extent of resources invested in each kind of experience and compare that investment with game harvested, hunter-days of participation, or other relevant data. The appraisal helps managers to better define and set standards for maintenance of the quality of hunting and fishing experiences. —PNW(297).

82. Land managers need new methods to analyze public reaction to land management issues and problems. A system has been developed that not only analyzes but also stores and retrieves information on public opinions submitted to managers via personal letter, petition, report, or other means. The system allows managers to quickly summarize public involvement data for decisions on resource management. —PNW(290).

83. Pertinent principles in communications research are not being applied to maximum advantage in environmental education and interpretation programs. Twenty-eight principles of communication are presented and used as an index to 57 annotated references. Results will help specialists in education and interpretation to use words, symbols, analogies, situations, and stereotypes that audiences will understand. —PNW(292).

84. Communication skills are not always used as effectively as possible by resource managers when they attempt to interpret ecological information for the public. Research has shown that to have maximum viewer interest, the interpretation must be dynamic, rewarding to visitors, easily obtained, tailored to diverse visitors, and meaningfully structured. Adaptation of these principles will improve the effectiveness of interpretation by attracting more visitors and holding their attention longer. —PNW(313).

85. Managers of campgrounds need techniques for maintaining vegetative cover without restricting visitor use. Ground cover vegetation was reestablished in a heavily used area through an intensive water-seed-fertilizer combination treatment at a cost of 29 cents per visitor day. Intensive vegetation management, combined with programs to inform and enlist campers cooperation, can be used to create and maintain attractive campsites. —PNW(287).

86. Land managers are continually seeking more effective means of involving diverse interest groups in the development of agency goals. Research suggests that the use of small working groups, with sustained interaction among representatives of conflicting interests, offers a viable solution. If management goals are to reflect informed opinion, compromise, and opportunities for mutual advantage, then managers and conflicting interest groups must interact sufficiently to identify tradeoffs. —PNW(314).

87. Resource managers need to know how recreational carrying capacity can serve as a criterion in the allocation of recreation resources. Several concepts are described that meet this need. By reviewing the potential consequences of alternative strategies, managers can better define the kinds of satisfactions to be provided, who the principal recreation clientele will be, and what recreational opportunity options are precluded for a given decision. Such an assessment of social impact is required by the National Environmental Policy Act of 1970, but little has been accomplished up to now, on how such impacts should be articulated. —INT(310).

88. How to obtain and effectively use public input in making resource management decisions is a problem that confronts resource administrators at every level of government. Processes for obtaining, analyzing, and evaluating public input have been described, and the importance of both the quality and quantity of public input discussed. By increasing public participation in the decision making process, public agencies may be able to avert mistakes and diminish ex-post-facto confrontations. —PNW(299).

89. Some of the most challenging questions that resource planners ask are: What do natural environments mean to people? How do different recreationists perceive one another? and how do recreationists feel about managers of natural environment? Research has quantitatively described the difference and similarities in how three groups of recreationists—auto campers, wilderness hikers, and picnickers—perceived each other, the natural environment, and resource managers. Results contribute toward a better understanding of the way recreationists relate to outdoor environments and what they expect from those environments. —NE(305).

90. There is a need for recreation researchers to work closely with land managers in order to relate research findings to management needs. The Marquette Workshop was one effort to promote this interaction. The proceedings contain 15 papers whose subjects include social and esthetic considerations, economic problems, and design and development of sites. These state-of-the-art papers are intended to summarize new technology and information for recreation management programs. —NC(311).

### Environmental Tree Culture

91. Urban microclimates are characterized by local extremes of temperature, solar and terrestrial radiation, and wind speed. Strategic location of tree stands in urban areas can ameliorate these severe conditions. Shielding of terrestrial radiation and interception of solar radiation by trees are major factors in reducing radiation and temperature extremes. Local rates of air flow may be reduced by vegetation. City planners and urban foresters can use this information to provide more desirable microclimates in cities. —NE(741).

92. Many of the sounds present in urban atmospheres are unwanted. Sound barriers in general fail at night because of refraction over the barrier. However, trees and shrubs, particularly when used with land forms and structures, can play a

significant physical role in noise control. This information can be used by city planners. —NE(742).

93. The need to quickly alleviate a noise problem often does not allow time for development of effective shrub-tree barriers. Sound levels can commonly be reduced by 10 to 15 decibels (less than half as loud) with 12-foot-high land forms combined with wide belts of tall trees. Trees or solid barriers may be used separately, but the combination provides more uniform control for a greater distance than either one alone. Effectiveness of tree-covered land forms is now quantified and being used by highway engineers, landscape architects, foresters, and others to reduce noise from disturbing to acceptable levels. —RM(740).

94. Relatively narrow, but dense and tall shrub and tree barriers—in conjunction with walls, terraces and fences—have now been found to reduce suburban noise from a 70 to 75 decibel level (rather noisy) down to a 62 to 67 decibel level (generally satisfactory for daytime outdoor environments). Conifers and broad-leaved evergreens are more effective on a year-round basis than deciduous trees, and the range of suitable material is diverse. These data can aid the nurserymen and others designing effective landscape plantings for the reduction of suburban noise. —RM(743,744).

95. Many older windbreaks throughout the Great Plains need renovating—not only to improve their vigor and effectiveness, but for foresters to keep abreast of changing agricultural practices. Eastern redcedar, ponderosa pine, and Austrian pine seedlings were planted in a portion of a 10-row shelterbelt where half the rows were removed and subjected to five cultural treatments. Survival and development were best with complete mechanical cultivation, mowing, and complete chemical spray; and poorest with chemical and mechanical strip treatments. Site preparation and cultural treatments are recommended for replacing rows of deciduous trees with evergreens in decadent windbreaks in order to prolong and increase the effective life of established windbreaks. —RM(745).

96. Multiple leaders often develop on sheared Scotch pine Christmas trees. The deformed trees which result require considerable labor to correct. Recent research in Kentucky shows that removing all but one potential terminal bud from the tree leader during the dormant season reduces the number of trees with multiple leaders. Scotch pine Christmas tree growers therefore benefit from this simple procedure, which can be done during a slack time in their schedule. —NE(746).

### Ecology and Classification of Natural Vegetation

97. Limited data have been collected for the forest vegetation on the western slopes of the Cascade Range in Oregon. Twenty-tree forest communities, arrayed along moisture and temperature gradients, have been provisionally recognized in two distinct forest zones, the *Tsuga heterophylla* and the *Abies amabilis*. This information is being used to stratify areas for extensive ecological research under the International Biological Program and for silvicultural prescriptions. —PNW(634).

98. Cascade Head Experimental Forest is a facility established for research on the very productive coastal "fogbelt" hemlock-spruce forests, yet little has been reported on the fauna of this coastal area. An annotated checklist is now available and includes 9 amphibians, 2 reptiles, 35 birds, and 40 mammals. A standardized habitat classification is presented in an effort to correlate the vertebrates in a meaningful way to their environment. Data will provide a



valuable basis for future research on fauna which inhabit hemlock-spruce forests. —PNW(649).

99. Fields of thin-leaved huckleberry (*Vaccinium membranaceum*) are dwindling in area and productivity throughout the Pacific Northwest. Greenhouse trials in Oregon indicate that nitrogen has a greater effect than potassium or phosphorus on huckleberry seedling growth. Fertilization of wild huckleberry fields with ammonium sulfate at rates of 40-160 pounds per acre greatly stimulates vegetative growth. These findings provide a physiological data base for future berryfield fertilization. —PNW(651).

100. Species identification of young tree seedlings is often difficult because most morphological descriptions are based on mature specimens. Studies in Wisconsin have resulted in the construction of an identification key based on seedling and needle characteristics of eight North American spruce species. Needle shape, margin separation, and needle apex are important characters in the key. Nurserymen and researchers can use this key to make difficult species identifications in seedlings. —NC(731).

101. Forest and land-use planning is actively underway for both public and private lands in New England, but basic information relating vegetation to soils and physiography is scarce. Transects on an undisturbed and a cutover mountainside in New Hampshire provided information on maximum tree sizes, species composition, and species limits related to elevation, as well as probably trends in species movements up and down slope. When cutting is eliminated, the natural ranges of beech, yellow birch, and sugar maple move uphill to their upper limit of about 2,800 to 3,100 feet in elevation, while spruce and fir ranges tend to retreat. This information currently provides the best foundation for the use of elevation in forest land use planning in the White Mountains of New Hampshire and similar adjacent areas. —NE(643,645).

102. Public interest in wilderness and natural areas is high, but little is known about the long-term effects of forest preservation on vegetation, soils, and streamwater. A study of age distribution in virgin northern hardwoods in New Hampshire indicates that: (1) The stand is moving towards stable populations of beech, sugar maple, striped maple, mountain maple, and hobblebush; (2) the humus has stabilized at a depth no greater than that found in stands cut 70 or 80 years before; and (3) the streamwater contains summer concentrations of  $\text{NO}_3$  ranging between 1 and 5 ppm. The results indicate that preserved northern hardwood forests will tend toward reduced tree species diversity, stable humus depths, and, possibly, fairly high levels of  $\text{NO}_3$  in the streamwater. —NE(644).

103. With increased interest in maintaining species diversity, better knowledge of ecological requirements of herbaceous as well as timber species is needed. A lay-level article describes the habitat distribution of flowering herbs in the pine barrens of New Jersey and contrasts floral composition of undisturbed and disturbed areas of various types (e.g. logged, burned). Information can be used by land managers and recreationists to locate popular wildflowers. —NE(646).

104. Understory plants in pine stands aid in nutrient cycling and provide shelter and food for game. A survey of a 33-year-old loblolly pine plantation in the Piedmont of North Carolina found 19 families, 45 genera, and 59 species of vascular plants. Twenty-one species of *Fabacea* (formerly *Leguminosae*), most of which fix nitrogen, and two other species known to fix nitrogen were identified in the survey. Propagation of selected pine species and development of management methods for their growth may improve the soil in southern pine plantations. —SE(639).

105. A current inventory of rare and endangered tree species was prepared to aid in their study, protection, and preservation. Thirty-five of the 96 species of conifers (cone-bearing evergreens) native to the continental United States are rare or local. Occurrences of rare or endangered trees are mapped and cited by public forests, parks, and other preserves. This compilation provides essential information for those who study, manage, and protect rare conifers. —WO(735).

106. The numerous native and introduced tropical forest tree species of Puerto Rico require special, detailed studies for their identification. A new illustrated reference contains descriptions and drawings of 460 species, briefly describes 40 other species, and provides keys to all 500 species. Common names, including those from other countries, are given and indexed. This reference is useful over large areas in tropical America as well as along the southern border of the continental United States, where tropical trees are planted. —WO(736).

107. An up-to-date guide for identification of trees is needed in Alaska, particularly because of the rapid development of land-use planning and forestry programs. A new guide has been prepared that describes and illustrates 32 species of native trees, mentions briefly six species of shrubs rarely reaching tree size, and contains keys, notes on occurrence and uses, small maps, and a vegetation map. This nontechnical reference is for all who are interested in trees, including foresters and land-use planners, residents and tourists, students and teachers, scientists and conservationists. —WO(738).

108. Detailed maps of natural distribution of plant species are essential for many uses, such as in land-use planning and management, wild plant utilization, and seed collection. A new atlas maps distributions of 82 species of Alaska trees and common shrubs. Also, 23 general maps summarize environmental factors and supply background information on geography, geology, climate and vegetation. This reference aims to provide preliminary answers about where each species grows and why. —WO(739).

## Improving Environmental Quality Through Fire Management

### Fire prevention, hazard reduction, and prescribed burning

109. Man-caused fires are still a major problem in the deep South. A personal contact program in fire prevention reduced man-caused wildfires in a Louisiana parish 55 percent over a 5-year period. Guidelines have been developed for planning and conducting additional personal contact programs for other areas. Decreased fire control and fire damage costs are the overall result of these efforts. —SO(550).

110. Prescribed fire is used extensively in forest management throughout the southern United States. During 1972, fire was used on almost a million acres of forest and agricultural land in Georgia alone. It is important to be able to assess the total environmental impacts of open burning. Quantity and quality of smoke produced by fires sampled to date indicate particulate production rates vary between 15 and 158 pounds per ton of fuel. Information is being assembled to establish relationships which exist between fire type, fuel type, fuel moisture content and particulate emission rate, concentration, and size distribution. Methods for determining particulate source strength emission factors for low-intensity prescribed fire have been developed. A smoke volume model has been developed with prediction accuracies of 75 percent or better based on limited test data. These efforts will continue to pro-

vide needed input to more completely assess the environmental impacts of prescribed burning. —SE(556,566,572,573,575).

111. The widespread use of prescribed fire in the South has brought about a need for burning guidelines. Such guidelines are necessary to maximize the positive environmental effects while minimizing the negative impacts. To date, guidelines for burning have been prepared for several land management goals including both site preparation and enhancement as well as hazard reduction. In the southeastern Coastal Plains, prescribed burns every 3 years forestall possible wildfire damage. General guides have also been developed to reduce the impact of smoke and to meet current local and regional regulations and standards. —SE(544,557,560,561,563,567).

112. Television public service directors in California were asked to rate fire prevention film spots they had received from the California Division of Forestry. Most directors rated them high in technical quality and interest. Delivery of the films by a fire prevention officer impressed directors favorably. However, fire prevention announcements generally ranked low in likelihood of selection for showing. Showing might be increased by giving the announcements a local flavor, tying them in with public health, conservation, and the environment, and giving greater attention to personal delivery of the films by fire prevention officers at an appointed time. —PSW(542).

113. Most people in Butte County, California listen to the radio and watch television, but they differ widely in the way they use these media depending on their demographic, social, and economic characteristics. Fire prevention planning should capitalize on these differences in developing mass media communications. In improving the prevention message dispersion, we can ultimately save fire control dollars and needless waste. —PSW(554).

114. In fuel types where fire propagation is primarily through the crowns of vegetation, the moisture content of the living fuel has a major effect on the rate of fire spread and on fire intensity. Seasonal variations in living fuel moisture often exceed 200 percent. New sampling methods and a simple "do-it-yourself" technique have been developed for obtaining the moisture content of living fuel for fire control and prescribed burning applications. This information can help the fire boss in his decisions about fire control and fire use. —PSW(545).

115. A substantial reduction of railroad-caused fires in New York State is linked to the cooperative efforts employed by the State's Department of Environmental Conservation. Among these efforts is a program of routine spark arrester maintenance and the use of a pyrometer sensor for isolating defective brake shoes and hotboxes. Additionally, a cooperative study with USDA Forest Service investigated the discontinuous application of phytocide chemicals on steep, erodable rights-of-way to reduce fuel hazard without environmental impairment. —NC(558).

116. Forest residues present fire problems, and are, in part, a function of existing utilization standards. Trends in log prices are a key to market conditions, and such information is needed by both industrial and public forest managers. A sharp upturn occurred in prices for all log species in 1973 in Oregon and western Washington. This has encouraged greater logging utilization, especially where low quality logs, formerly left as residue, can be substituted for higher priced logs in the production process. More complete utilizations reduce the fire hazard. —PNW(541).

117. Utilization of wood residue provides more material for products and energy and at the same time reduces fire hazard and environmental impacts of converting the timber resource.

The latest national data available are used to present volume and location of unused forest residue, primary mill residue, secondary plant residue, and bark. Information on residue location and availability is needed by manufacturers looking toward possible large-scale use of residues in new plants or processes. —PSW(552,553).

118. Information is lacking concerning the use of helicopters as a forestry tool. There is a specific need to harvest commercial timber from steep slopes where access is difficult. This need has led to public concern over the adequacies of conventional logging systems. General information has been developed summarizing factors relevant to the productive and safe use of helicopters for timber harvesting, with emphasis on candidate helicopters and their characteristics. Comparisons of yarding rates with costs for helicopter, balloon and cable yarding systems have been made. This initial information provides the basis from which more environmentally sound resource management decisions can be made. —PNW(551,570).

119. Environmental effects of excess, unwanted, living or dead woody material in forest areas are poorly understood yet often of great importance to such forestry considerations as nutrient cycling and soil management, wildlife habitat, forest regeneration and growth, esthetics and recreation, forest fire management, fish habitat, and water quality. Treatments of these residues, with or without fire, have substantial effects on the environment. A collection of articles by 29 authors defines the present level of knowledge and identifies the residue-related problems most in need of research attention in the Pacific Northwest in various components of the forest environment. —PNW(547).

120. Prescribed burning and forest wildfires produce smoke that may result in an air pollution nuisance. The amount of smoke produced varies with fuel and burning method, and the dispersion of the smoke varies with fire characteristics and weather conditions. Smoke management is a necessary part of quality forest environmental management where wildfire or prescribed fire are present. —PNW(546).

121. Slash is often burned to reduce the hazard of accidental wildfire, but the need for regulating air quality must be weighed against the hazards from wildfire. Thus, evaluation of this pollution source depends on a detailed knowledge of the nature and amounts of emissions from slash burning. Recent tests showed that the smoldering phase of combustion is of major importance to air pollutant production during slash burning. The initial 80 percent of the fuel burned accounted for only 20-30 percent of HC and CO emissions. This suggests that a rapid mop-up of slash burns could substantially reduce air pollutant production. —PNW(568).

122. Improved techniques for precommercial thinning and slash treatment are needed for overstocked pine stands in eastern Oregon. The Trakmac machine has a boom-mounted cutting disc, enabling the operator to select individual trees for cutting, sever the stem near ground level, and treat the resulting slash in one operation. Both branches and boles of cut trees were reduced to small, well-scattered pieces. This treatment speeds natural deterioration and results in an immediate reduction of fire hazard. —PNW(574).

123. An understanding of emissions from open burning of forest residues is needed to avoid negative environmental impacts and meet local air quality regulations. Study in ponderosa pine slash showed average particulate emission to be 12.5 lb/ton of fuel burned while Douglas-fir slash averaged 6 lb/ton of fuel burned. Eighty-two percent of the particulate mass was in the submicron range. Particle size distribution did not depend on fire intensity while flaming still existed. Infor-



mation developed in this study will assist in designing burn prescriptions which will result in minimum emissions and attendant air pollution. —PNW(569).

124. Land managers need to know how much crown slash will be created by various harvesting methods when developing management plans and strategies. The amount of slash produced determines the fire hazard due to logging. Study results in Oregon and Washington indicate Douglas-fir biomass (slash) less than 7.62 cm in diameter can be predicted from tree diameters, an easy-to-obtain measurement. Several prediction equations were developed for determining tree crown residues. Data and procedures which were developed provide objective quantitative assistance to land managers for sound multiple use decisionmaking. —PNW(576).

125. Development of conflagrations is dependent upon—among other factors—weather, terrain, and large accumulations of residue or fuel. Theoretically, by strategic manipulation of residues, the forester is able to trade routine cost of hazard reduction for cost of emergency conflagration suppression. He cannot control the weather or terrain. Fuels accumulate in natural systems, but man's actions may greatly modify the nature of the fuels, and thus, the hazard. Each fuel component has its own characteristics, thus making its specific contribution to hazard. Integration of fuel management planning with other phases of forest management planning will help to achieve a pattern of fuels and low hazard areas compatible with fire management and environmental objectives. —PNW(559).

126. A need exists to reduce ground fuels and abate the wildfire hazard in established stands of west-side Douglas-fir in Oregon and Washington. Initial results of limited study indicate that from about 40 percent to over 80 percent of roundwood fuels, depending upon diameter, can successfully be removed using fire. Some tentative prescription criteria have been developed. The information provided, along with burning procedures, will assist land managers in meeting their multiple-use objectives. —PNW(571).

127. A question facing land managers is: "Exactly how much does increased utilization of residues reduce the fire hazard, compared to conventional utilization?" Fuel and fire potential in clearcut lodgepole pine, (*Pinus contorta* Dougl.), was compared after stands were logged to near complete and conventional utilization standards. Logging to such standards reduced fire potential to a point that no further fuel modification should be required for hazard reduction. Logging to conventional utilization standards left the fire potential high enough to warrant fuel modification for hazard reduction. Results are useful for planning timber sale activities. —INT(543).

128. In 1972, the Forest Service initiated a practice of allowing lightning caused fires to burn unchecked in certain wilderness areas so that fire could assume a more natural ecological role. The first real test of the concept came in the summer of 1973 when the Fritz Creek Fire in the Selway-Bitterroot Wilderness Area was allowed to burn for 42 days and reach a size of 1200 acres. Analysis of this fire's effects clearly demonstrates that with careful study, sound fire management prescriptions can be written to allow fire to play a more natural role in wilderness ecosystems. Prescriptions must, however, be applied carefully and with full attention to proper suppression techniques when suppression action is required. —INT(585).

129. It is important that the land manager have a general perspective as to the amount, reason, and conditions under which prescribed fire is used within his general geographical

area. During the period 1968-1972, prescribed fire has been used on 76,743 acres in Minnesota, Wisconsin, Michigan, and Ohio. Most of the burning has been for wildlife habitat work and was conducted in late April and early May or late July to early August. This summarized information provides land managers a basis on which to plan and to compare their current operational procedures. —NC(548,549).

130. Resource managers need procedures to take some of the guesswork out of the decisionmaking process. A series of computer generated (CALCOMP) graphs has been developed to display potential fire behavior in logging slash of seven northeastern tree species. These objective criteria can be used to help decide whether slash treatment is needed, treatment method alternatives, and how priorities could be assigned when several areas require treatment. —NC(565).

131. Sprouts of many hardwoods are favored foods of white-tailed deer, but generally are undesirable for timber production because of poor quality. Sprouts from hardwood trees killed by a prescribed fire on the Chippewa National Forest, Minnesota, were most vigorous from basswood, red oak, and paper birch. American elm, bur oak, ironwood, and red maple were intermediate sprouters, while sugar maple and yellow birch sprouted poorly. Burning encourages sprouting close to the ground line which is beneficial to red oak, and probably other species, because decay entrance from the parent tree is reduced. —NC(564).

#### Fire management methods and systems

132. The field of fire management has generated a terminology to express the role of fire in wildfire suppression. However, this terminology has developed on a regional basis. Adoption of the proposed terminology would promote a universal understanding by providing a simple common definition for the fire suppression terms. Improved communications would result. —SE(587).

133. Computer calculations of National Fire Danger Rating System (NFDRS) values can be costly and differ from those developed by using tables. Although differences between table- and computer-derived NFDRS values do exist, study indicates no significant problems will result. Guidelines have been developed to assist computer timeshare users in attaining the most economical machine use. Continued computer use and application in danger rating will enhance our ability to store and retrieve data for future use as well as improve daily utilization. Development of a computer system will also assist us in all forms of planning. —RM(586,596).

134. Because of unusually wet weather during early 1973, the Bureau of Land Management was faced with more than normal grass fuels over much of the Southwest. This resulted in an urgent need to prepare a fire plan for 600,000 acres of high-value, high-fire potential lands in Arizona. Agencies cooperated in making and evaluating the plan (using the FOCUS simulation model) in less than 30 days. The emergency fire plan included all phases of fire management and combined basic research, applied research, and practical knowledge in its preparation. —PSW(589).

135. Most computer data storage and retrieval systems for map-type information require much hand coding and computer storage capacity. A procedure has been developed that requires only the description of the map area boundary. This technique describes the boundary as a set of short line segments that can be defined in terms of a multi-dimensional polygon. Preliminary tests show that about one-tenth the hand labor and computer storage is required for this method compared to other techniques. As additional support for manage-

ment, a computer system has been developed and put into use that quickly and inexpensively prepares three-dimensional histogram charts of computer fire statistic records. The system allows fire control planners to visualize their fire occurrence problems at a glance where previously they would have spent many hours reading through historical records. —PSW(591,592).

136. Conflagration fires account for most of the fire damage and loss of life from wildland fires in southern California. Quick suppression of wildland fires with conflagration potential in this area is made difficult by a distinctive complex of fuel, topography, and weather; and is further complicated by the influx of people and suburban developments into the wildlands. Enlarged fire control forces, improvements in firefighting techniques, intensified fire prevention, and better organizational structures appear to offer little hope for alleviation of the conflagration problem. The best solution is the modification of the vegetation to reduce fire energy output through the creation and management of fuel type mosaics. —PSW(584).

137. The Administrative and Forest Fire Information Retrieval and Management Systems (AFFIRMS) provide an interactive national computer network for automation of the National Fire Danger Rating System and message traffic routing. AFFIRMS is a user-oriented system. The user's guide contains instructions for use of all thirty AFFIRMS commands, a terminal operations manual, and a complete directory of error messages, their meanings, and appropriate user action to correct each error. The guide is in use by the Forest Service, National Weather Service, Bureau of Land Management, and State forestry agencies for training and operation nationwide. —RM(555).

138. The most cost-effective means of wildland fire protection for the Santa Monica Mountains in California is for all houses to have fire-resistant roofs and 100 feet of brush clearance. If this plan were implemented, structural losses could be reduced by almost a factor of ten, decreasing the present average burn rate of 60 houses per year to a rate of only 7 houses per year. Although wildfire is inevitable in the Santa Monica Mountains, homeowners, developers, local government officials, insurance executives and bankers should be made aware that certain protective measures can greatly reduce wildfire losses. —PSW(594).

139. Oak-hickory forests are important natural and renewable resources in the eastern United States. Estimation procedures for future sawtimber losses due to fire-caused wounds are given in terms of: 1) Lumber value in dollars, 2) volume in board feet, 3) length of defect, and 4) area of defect. The predictive models apply to all major oak species endemic to the oak-hickory forest types. Application of these procedures should help avoid needless loss of an important forest product. —NC(590).

140. In 1971, the Carrizo Wildfire on the White Mountain Apache Reservation in Arizona burned 57,335 acres of commercial forest land. Some of this area had been treated by controlled burning a year earlier. Although much timber was damaged or killed, the fire had many beneficial effects—range and wildlife improvement through increased forage production, thinning overstocked young timber stands, and consumption of surface fuels resulting in reduced fire hazard. Fire studies are underway to determine the influence of controlled fire and wildfire on a ponderosa pine ecosystem. —PNW(616).

141. Wildfires in Alaska can produce considerable smoke under specific meteorological conditions. In a region so dependent upon air transportation, wildfire smoke could present

problems. Records of 21 stations were analyzed for the occurrence, persistence, and related visibility resulting from summertime wildfire smoke and haze in interior Alaska. Smoke persistence and impaired visibility were not found to the extent previously assumed. —PNW(581).

142. Practical methods for inventorying volumes of downed woody material to provide an objective basis for managing debris have been lacking in the past. Procedures which have been developed and prepared in handbook form are quick and easy to use and can be applied to naturally fallen debris and slash. Instructions show how to estimate weights and volumes of downed woody material, fuel depth, and duff depth. Inventorying downed woody material can help land managers practice fuel management, plan for prescribed fire, estimate utilization potential, and communicate in exact terms about their debris problems. —INT(582).

143. The fire manager needs to know where to apply chemical retardants, in what concentration, and in what form for various fire situations and fuel types. Results of a series of tests showed that the proportion of retardant retained on fuel arrays increased as the fuel diameter and surface roughness of individual fuel elements increased. Equations describing retention were developed and extended to actual field situations; results agreed with published findings on the transmission of rain. The results of the retardant drop tests provided equations that relate retardant retention to fuel size, and illustrated the types of distribution that can be expected under tree canopies. This information contributes to guidelines for the use of retardants to control wildland fires. —INT(578).

144. Wildland vegetation can be quantified into various classes of fuels, but it also needs to be appraised for fire potential to aid in fire management activities. Elements making up fuel appraisal are defined and a concept for appraising fuels, using inland Douglas-fir (*Pseudotsuga menziesii*) as an example for fuel, is presented. Fuel appraisal elements that can be used now include rate of spread, fire size, fire intensity, and crowning potential. The concept presented can provide the land manager with a decisionmaking tool for quantifying fuel appraisal. —INT(579).

145. An estimated 17 million gallons of retardant valued at 23.5 million dollars were delivered in 1970. This widespread use presents an urgent need to increase the efficiency and safety of fire retardant air operations. Considerable effort has gone into the development of static and drop test data including simulation models. Rheological properties, aerial drop behavior, dispersion characteristics, and wetting-out properties have been tested and evaluated. Various forms of delivery systems—including large military helicopters—and delivery criteria have been tested. Guidelines in an easily used form to help air tanker pilots, air attack specialists, and ground personnel obtain optimum retardant coverage under various operational conditions have been developed. The basic research and guidelines provide means by which safe, productive, and economical use of retardants can be implemented. —INT(577,580,597,598).

146. Because of both safety and cost implications, we must be able to assess the severity of fire retardant-caused corrosion on air tankers and mixing plants. In the laboratory, the effects of five operational retardants on ten aircraft and pump alloys were investigated. Results indicate, in part, that fire retardants currently used can be corrosive to aircraft, and that corrosion rates vary for each alloy and retardant formulation combination. Only stainless steel alloys were unaffected by commonly used retardants. However, the use of additional inhibitors can reduce corrosion markedly on any of the alloys tested. Study results and recommendations provide the basic



information to develop safe products with acceptable corrosion levels designed to meet field application and operational requirements. —INT(588).

147. Improved capabilities for safely attacking forest fires in a wide variety of terrains are urgently needed. The feasibility of using large military type rotary winged aircraft (Chinook helicopter) was evaluated. The Helicopter Modular Airborne Fire Fighting System (H-MAFFS) test demonstrated large helicopters can be used to deploy forest fire retardants. No aircraft equipment modifications are necessary. Retardant concentrations can be easily controlled as can drop altitudes. H-MAFFS is quickly off loaded (30 minutes or less) making the aircraft immediately available for other missions. No adverse helicopter control or emergency jettison procedure problems were encountered. Use and development of multi-purpose retardant aircraft systems allows utilization of existing equipment and minimizes capital investment in specialized aircraft ultimately saving considerable funds while improving efficiency. —INT(583).

148. Legitimate concern for air quality requires that the impact of smoke from prescribed fires must be minimal. Twenty-two documented 10-acre slash fires in the western larch/Douglas-fir type of western Montana were analyzed for factors related to ultimate smoke column heights. Contrary to accepted theory, atmospheric stability was not of great significance in describing smoke rise. Factors directly related to fire intensity were the important descriptors of column height. Management guidelines based strictly on meteorological factors are possibly too restrictive and inaccurate in representing actual smoke behavior, hence many burning opportunities are being missed. —INT(607).

149. Development of understory burning techniques requires the establishment of quantitative relationships between preburn conditions and fire effects. Twenty-two experimental plots in a Douglas-fir/western larch stand in western Montana were burned to determine the effects of prescribed fire on fuels, vegetation, soils, nutrient cycling, and air and water quality. These fires were conducted over a wide range of fuel and weather conditions to produce a range of fire intensities. Preliminary results indicate that it may be possible to accurately predict the effects of various types of fires on these forest lands. —INT(614).

150. The Bureau of Land Management used a converted DC-6B airliner as a retardant bomber during the 1971 and 1972 fire seasons in Alaska. Daily minimum prices, daily minimum and hourly rates, and cost per retardant mile or gallon compared favorably with other aircraft currently in use. —INT(595).

151. A recent publication contains 910 sets of forest fire ecology questions mailed to 302 land managers and scientists throughout the western United States and western Canada. The questions cover the entire spectrum of environmental parameters affecting and affected by fire. The question sets collectively express the most important information needs for those managers who require an understanding of the ecologic effects of fire. —INT(599).

152. Major considerations regarding fireline construction in interior Alaska are protection of the fragile tundra environment and costs. Evaluation was made of a Franklin articulated all-terrain log skidder equipped with a double-backup pump system for retardant or water delivery and a propane weed burner for burning out and backfiring. Over 79 machine days and 1250 hours of actual use were compiled in 1971 with no down time. It proved less damaging to surface environment than crawler tractors. Fire suppression performance was outstanding. —INT(600).

153. Fire management prescriptions for a 100-square mile study area in the White Cap and Bad Luck Drainages of the Selway-Bitterroot Wilderness were established and approved in 1972. These prescriptions were based on investigations of wildland fuels, plant communities, landforms, and fire spread and intensity potentials. A lightning-caused fire burned for 43 days in August and September of 1973 in the ponderosa pine savanna, shrubfield, and ponderosa pine/Douglas-fir zones of the study area. Among the observed effects of this fire was a significant reduction in all sizes of fuels except the surface litter, which in some cases increased due to fresh needle fall from scorched lower branches of trees in the burned area. The results of this work will be valuable toward applying this concept to other wilderness areas in the West. —INT(593).

#### Forest fire science

154. Basic information is needed to more adequately model and predict forest fire behavior. In response to this need, research efforts indicate that buoyancy production rates for a pure heat source and for a fire heat source of burning woody fuels show that fire may be regarded as a pure source yielding heated air rather than heated combustion products. This finding simplifies development of scaling laws for modeling fires. Ultimately, we will be better able to predict fire behavior. —SE(605).

155. The burning of cellulosic materials, such as forest fuels, is preceded by very complex chemical reactions. The key to better understanding and control of fire depends upon obtaining more fundamental information about these reactions. Significant progress has been made in recent years, especially on the effects of heating rate and chemical additives. The improvement of fire control methods and techniques and the development of better fire retardant chemicals are the ultimate outcome of this work. —PSW(602,603,611).

156. The interaction of fire and local environment gives rise to the complex problems of fire behavior. A model was developed for the purpose of predicting the fire-induced effects upon the winds and temperature fields which are a result of the interaction of fire and local environment. The model employs local ambient winds as initial conditions and the flame front temperature as a boundary condition to solve a set of turbulence model equations making use of a "stream function vorticity algorithm." The outputs are the fire induced winds and temperature departure from the fire front. This model will ultimately be a useful tool for forest fire and wildland management, planning, forecasting, and decisionmaking with regard to initial attack and firefighting strategies. —PSW(613).

157. Wind, temperature, and humidity in the atmospheric boundary layer strongly affect the way a fire behaves. The rates of spread and fire intensity are shown by the fire's temperature history. Experimentally, fires were found to add heat to the air flows in ways described by modern turbulence theory. These results help in developing models of fire behavior in southern California chaparral fuels. —PSW(608).

158. An important factor in the flammability of forest and chaparral fuels is the fuel moisture. This is obtained by weighing the moist fuel, then drying and reweighing it. Research has shown that the microwave oven can be used to dry fuel. It is a fast, accurate, safe, and simple method, which can be used any place where there is a source of electrical power. This system provided the operational fire manager with fast, accurate fuel moisture information, which, for practical purposes, was previously unavailable. —PSW(609,610).

159. The planar intersect method is the most commonly used method of estimating slash fuel loadings in the U.S., Canada, and Australia, but it has two inherent biases. The biases were theoretically eliminated by using quadratic mean diameter of particles and average secants for particle angles. Mean diameter and secants suitable for 11 types of conifer and hardwood slash and naturally fallen debris were computed so the intersect method may be used without bias throughout the northern U.S. —INT(604).

160. There is a need to validate fire fuel models and rate-of-spread models developed through fire research efforts to date. Study results indicate that, using the current grass fuel model, Rothermel's mathematical fire spread model overestimates the rate-of-spread of low to medium intensity fires. By adjusting the moisture of extinction values and fuel bed depth, close agreement can be obtained between measured and observed spread rates. Additional findings indicate that the fire spread rate model is basically sound, but additional field verification studies are necessary in order to "fine tune" prediction equations for spread rates as well as the fuel model inputs. Improved capability to predict fire spread will enhance our ability to economically manage and control fire. —PNW(612).

161. Recent advances in the understanding of lightning and its effects include: 1) New evidence that a specific type of electrical discharge causes most lightning fires in forests; 2) a new hypothesis on how lightning ignites forest fuels; and 3) a fuller recognition that lightning—in addition to causing wildland fire—produces mechanical and physiological effects that are exploited by wind, insects, and diseases. These conclusions, together with the capability of lightning to render nitrogen from the atmosphere, qualify it as a powerful agent of change in forest ecosystems. —INT(615).

## Improving Insect and Disease Control

### Detection and evaluation

162. Grand fir is an important component of the mixed-conifer forests in the Blue Mountains of Washington and Oregon, but management of this tree has been difficult because of excessive defect. Timber cruisers were handicapped because accurate methods for making defect estimation in standing trees were not available. After dissecting 1,090 trees on 65 plots in the area, researchers have developed two methods for estimating internal defect. If these methods are adopted, the management of grand fir will be improved greatly. —PNW(435).

163. Black walnut is one of the most desirable timber species in the United States, but attempts to grow this tree in plantations are not always successful. A stem-girdling canker of young trees has been found in plantations in the Central States. Canker initiation and development are postulated to result from fungal invasion of the stem following injury by insects. Plantation managers in the Central States can minimize losses by controlling insect-breeding sites and practicing adequate stand maintenance. —NC(437).

164. Radiography is being used as a means of nondestructive testing in forestry and related fields, but its value in work with trees, seeds, and the organisms that affect them has not been realized. A simple system has been developed to explain the use of sensitometry for film selection and optimum film performance. Use of this system will enable scientists to obtain greater benefits from the use of sensitometry in soft-tissue radiography. —NE(436).

165. Decay in living trees and wood-in-use most often becomes viable only after most of the internal wood fiber at one or more points has been destroyed. To permit earlier recognition of internal defect, an instrument has been developed that will detect decayed or discolored tissues. The instrument consists of a long, slender probe that measures the difference in electrical resistance of wood fibers through a small-diameter hole bored for that purpose. With proper calibration, this instrument could be used anywhere by foresters, pathologists, and commercial tree management officials to determine the extent of degradation in trees, poles, pilings, and other wood products. —NE(438,441,442).

166. The most serious disease of forest trees in the southern United States is fusiform rust. A recent forest survey showed that 800 million slash and loblolly pines have stem infections with highest percentages in an area across central Georgia. Annual stumpage loss to infections on living trees exclusive of mortality was estimated at 28 million dollars. Forest managers will use these data to evaluate management options for forest lands in the South. —SE(439).

167. In Mississippi, a serious canker disease has been found on Formosan sweetgum, a tree introduced from Asia. The fungus associated with this disease is closely related to the chestnut blight fungus that destroyed the American chestnut early in this century. The chestnut blight fungus was introduced from Asia and the infection of an introduced Asiatic tree with a native American fungus suggests the possibility of a reciprocal epidemic in Asia should our Formosan sweetgum pathogen be introduced there. —SO(444).

168. Phloem necrosis, a lethal disease of elms, is getting renewed attention after two decades of relative obscurity. This disease, which has recently been observed in New York, Pennsylvania, and New Jersey, may be controllable by proper use of an antibiotic. Information on diagnostic features has been assembled. Arborists, plant pathologists, and entomologists in the West, South, and Northeast will be able to recognize diseased trees and make appropriate management adjustments. —SO(443).

169. The European pine shoot moth is most damaging in ornamental and plantation pines. In the Pacific Northwest, methods have been developed for detection trapping of this insect by using a synthetic sex attractant. Information is provided on dosage-response, controlled-release formulation, distance-response, trap placement, and seasonal timing. Entomologists in the northeastern, northern, and northwestern parts of the United States will be able to monitor European pine shoot moth populations more accurately with this technique. —PNW(315).

170. Ground checking is necessary to verify insect mortality observations on aerial photographs. A computer-aided sampling technique was combined with aerial photography to overcome this problem in a California pine stand infested with western pine beetle. The spatial distribution of dead trees was displayed on a map of tree-mortality spots visible on photographs, and a stratification scheme was devised to randomly select the spots for ground checking. Further use of this technique will increase the utility of aerial photographs and enable the land manager to assess and to adjust for insect-caused mortality more effectively. —PSW(317).

171. Wood-boring insects significantly reduce hardwood lumber grade yield and value in the eastern United States. An evaluation of oak-borer-caused losses in West Virginia, Ohio, and Kentucky showed that these pests reduce the value of red oak factory-grade lumber \$24 per 1000 bd. ft. The total loss from wood borer damage in standing sawtimber in the three-



State area is estimated to be almost half a billion dollars. The magnitude of these losses emphasizes the need for controlling borer-caused defect in oak forests. —NE(318,319,342,345).

172. Faster and more accurate techniques are needed to replace routine dissection and microscopic examination for studying insects and assessing insect damage to tree seeds. Procedures have been developed to nondestructively examine southern pine seed with x-rays. This information will provide the basis for a more rapid and standardized examination of many forest tree seeds. —SE(320).

173. Coneworms cause a major loss of seed in southern pine seed orchards, but their impact is difficult to assess. In northern Florida, second-year cones infested early in the summer fall from the trees before harvest, thus precluding an accurate assessment of coneworm damage. A regression equation, compensating for this premature cone fall, has been developed to estimate the total coneworm damage. Entomologists and geneticists will now be able to better evaluate the impact of coneworms and the effectiveness of chemical control treatments. —SE(316).

### Biology and understanding

174. Logging residues contribute to proper nutrient cycling, but they also may interfere with new growth and provide a habitat in which destructive insects and disease-causing fungi proliferate. Available information on forest residue deterioration was summarized and the research needed to learn better methods of inducing rapid decomposition has been identified. Foresters in the Pacific Northwest can now practice improved residue management. —PNW(445,449,483,484).

175. Wood-decay fungi have relatively nitrogen-rich vegetative mycelium, sporophores, and spores, but the source of this nitrogen has been questioned because heartwood, which is the portion of a tree most commonly decayed has a low nitrogen concentration. Bacteria from white fir in southwest Oregon were found to fix atmospheric nitrogen. These bacteria also were associated with the major decay fungi of white fir, and their high concentration indicates that they have an important role in supplying nitrogen to these fungi. Knowledge of this association will aid forest pathologists and physiologists everywhere who are investigating the basic principles governing cause and development of decay in trees. —PNW(446).

176. The needle-cast fungus, *Lophodermella morbida*, has been destructively epidemic in pine plantations in California and Oregon. Recent investigations suggest this is probably a native fungus catapulted to prominence in populations of a very susceptible host growing on unfavorable sites where climatic conditions favor disease spread. Recommendations have been developed for avoiding losses, and forest managers in that area will be able to minimize the impact from *L. morbida* by following these recommendations. —PNW(460).

177. *Phellinus (Poria) weirii* causes a serious root disease of conifers in western North America and measures to reduce fungus survival in dead root systems have not been developed. When urea was added at 600 0N/acre, fungus survival in buried wood was significantly reduced. This knowledge may lead to a treatment for reducing *P. weirii* root rot damage in the West. —PNW(482).

178. Pacific madrone cohabits with Douglas-fir in many places along the West Coast and the two trees often compete for soil nutrients and moisture because of a shared fungal absorbing system. Several symbiotic fungi form mycorrhizal associations with the two trees, and one of these fungi has been identified and described. This new knowledge will permit

research workers in the Pacific Northwest to better understand the interactions between these trees and to plan new studies with the objective of developing improved forest management recommendations. —PNW(520).

179. Many of the mycorrhizal fungi which form close association with plant roots have been neglected because few researchers know how to find and identify them. The ecology and methods of working with subterranean-fruited (hypogeous) fungi are now presented in handbook format. Researchers and mycologists throughout the country can include these important root symbionts in recommendations for enhancing tree survival and growth. —PNW(434).

180. Mycorrhizal fungi are essential to nutrition of most green plants but are little known outside North Temperate areas. On invitation of Mexican scientists, an exploration of Mexican subterranean mycorrhizal fungi was initiated in 1972. About 250 collections were obtained from tropical to subalpine forests. Early analyses of specimens indicate that many species formerly thought to occur only in the U.S. extend well into the tropics. These species provide a broad range of ecotypes for use as mycorrhizal inoculum in nurseries throughout the country. —PNW(511).

181. Dwarf mistletoes parasitize many coniferous species in the western United States, but efforts to do basic research that would provide information upon which to base control recommendations have been hampered because a method for producing infected seedlings on a continuous basis has not been available. A technique has now been developed which permits year-round production of uniform, infected seedlings. This methodology will enable researchers in the North and West to intensify dwarf mistletoe investigations. —PNW(468).

182. Nearly 95 percent of the world's plant species, including many forest trees and shrubs, are nutritionally dependent on mycorrhizal fungi in the family Endogonaceae, but these fungi are little understood, in part, because of difficult taxonomic problems. All the known species in the Pacific Northwest are now described and classified. For the first time, plant scientists in that area can identify the Endogonaceae that are involved in root symbiosis with higher plants. —PNW(454).

183. Prevalence of root rotting fungi may be influenced by the above-ground flora because higher vegetation affects numbers and kinds of soil microorganisms by affecting soil moisture, temperature, deposition of litter and production of root exudates or leachates. Soils under alder stands in Oregon had more species of microorganisms than either those under conifer stands or those under mixed alder-conifer stands. If some of the numerous organisms in soils under alder stands inhibit conifer root pathogens, forest managers in the Pacific Northwest should consider rotation of alder and conifer to improve conifer growth and vigor. —PNW(475,519).

184. Approximately 175,000 acres of Hawaiian ohia lehua forests are in various stages of decline. *Phytophthora cinnamomi* has been isolated from soil and from ohia lehua roots in the area. Although different soil types and ages of lava flow were involved, rainfall is adequate to perpetuate the fungus within the decline zone. The fungus is widespread in wildlands including forests on the island of Hawaii, and forest managers will have to select species and plan reforestation carefully should the damage be attributed to this fungus. —PNW(448).

185. The occurrence of European mistletoe, *Viscum album*, in California is the only known case of introduction, establishment, and spread of any mistletoe from one continent to another. Since its introduction in the early 1900's, it has infested an area north of San Francisco of about 16 square

miles, and has been found on 21 different native and introduced tree species. In California, *V. album* is not considered a serious economic problem because of its slow rate of spread and because the plant does only limited damage to commercial orchards. Foresters need not be concerned unless a virulent hybrid develops or the climate changes. —PSW(498).

186. Mistletoes parasitize woody plants throughout the world causing malformation, growth reduction, and mortality. The species of *Phoradendron* that parasitizes hardwood trees in the United States, their distribution, and methods for control have been popularly described. Mistletoes that infect woody plants growing outside their natural range or in ornamental plantings have been listed by species and host. Foresters, arborists, and individuals responsible for shade and ornamental hardwood trees can refer to this information which details occurrence and control of mistletoes in their plantings. —PSW(461,497).

187. Black stain root disease and the losses caused by it are becoming more important in second-growth Douglas-fir stands along the Pacific Coast. Current knowledge about this disease and some silvicultural treatments to alleviate its damage are described. The management options and silvicultural treatments will benefit forest land managers in the area. —PSW(510).

188. Development of methods for control of white pine blister rust has been impeded by lack of understanding of the biological interaction between pathogen and host. Bark from diseased western white pine has been found to have significantly less pectin but more materials extractable in petroleum ether and ethanol than bark from uninfected trees. In pure culture, enzyme (ribonuclease) activity increases with increasing age and new forms develop that possess unusual catalytic properties. Such results suggest that the host plays a major role in disease development. This information will permit research workers to test new techniques in the search for an acceptable strategy for controlling white pine blister rust throughout the range of five-needle pines. —INT(458,515).

189. Study of the nutrition of the white pine blister rust fungus has been hampered by inability to grow the fungus on artificial media. A defined nutrient medium was developed that supported fungal growth and upon which the fungus subsequently developed immature spores, re-infected germ-free host tissue, invaded leaves of the alternate host, and produced spores. This knowledge will permit researchers to explore new avenues for control of white pine blister rust. —INT(459).

190. Some western white pines resist infection by the white pine blister rust fungus, but the mechanism for this resistance is not understood. In culture, host tissues and fungus interact prior to, during, and after invasion. The exact host-fungus appearances at each stage of invasion of both tissue culture and tree bark were determined by electron microscopy. Appearances suggest that the fungus feeds primarily when in contact with host cell walls, and that the fungus might be controlled in spaces of bark tissues. This information will assist researchers who are investigating the biology and attempting to develop materials for control of white pine blister rust. —INT(494,495,514).

191. Pole blight is a very serious killing disease of western white pine that appears related to rootlet deterioration and consequent lack of water available to the tree. The symptoms of pole blight did not develop on 85-year-old trees deprived of some or all precipitation for 13 years. Upon excavation, vertical roots were found to have extended into water layers deep in the soil before the study was begun. The forest manager

cannot predict occurrence of pole blight on the basis of low precipitation alone, and future researchers should investigate the relative capabilities of conifer root systems to competitively obtain nutrients. —INT(473,474).

192. Dwarf mistletoe does not occur in the heart of the Douglas-fir range in western Washington and Oregon although common to the species elsewhere. While the parasite now appears to be invading the area, it is believed to have been excluded in the past by individual host and parasite requirements, climate, physiography, forest ecology, and succession. Although all facets of the interrelationship are not known, land planners and managers should always consider the possibility that a substantial change or alteration in the forests may induce a massive dwarf mistletoe invasion of this important timber producing area. —INT(518).

193. Information on seed viability, germinability, dormancy, and longevity was unknown for some species of dwarf mistletoes, which are a major cause of reduced growth and death of western American conifers. A brief period of physiological dormancy is indicated for four taxa tested, but no particular unusual conditions are required for germination. Optimum storage temperature is near 0°C under low relative humidity. Inoculations with dwarf mistletoe seeds would be considerably enhanced if collection, storage, and germination treatment guides established by this study are followed, and results from such tests would permit more effective recommendations for control of dwarf mistletoe in the Western United States. —INT(517).

194. Southwestern dwarf mistletoe (*Arceuthobium vaginatum*) is the most damaging disease of ponderosa pine in the southwestern United States and in parts of the central Rocky Mountains. The available information on host relationships, life cycle, ecology, damage and control recommendations for this serious pest have been summarized. This information will enable forest managers in the affected area to minimize dwarf mistletoe damage on their lands. —RM(476).

195. Dwarf mistletoes are insect-pollinated and at that stage in their life cycle they may be amenable to control. To better understand the pollination attraction mechanism, nectar produced by pistillate flowers was analyzed by thin-layer and gas-liquid chromatography and found to contain 58-92 percent sugars composed primarily of glucose, fructose, and sucrose. This high sugar content is probably a strong insect attractant and also may be a major factor contributing to the spread of this disease. If this relationship can be established, researchers will have additional information upon which to base control strategies for dwarf mistletoes of northern and western coniferous forests. —RM(450,455).

196. As containerized forest tree seedling production is increased, the diseases that reduce quality or kill plants become more important. The fungi and nematodes that cause damping-off, root rot, foliage diseases, and seedling blights have been identified. Conditions in seedling production facilities that promote disease development and controls for some developed diseases have been described along with possible causes and preventions for physiologic chlorosis or yellowing of containerized seedlings. Nurserymen throughout the United States will be able to use this information to identify and control new problems as they arise. —RM(490).

197. Large numbers of seedlings are produced in forest tree nurseries, but omnipresent diseases caused by fungi, bacteria, and nematodes reduce production unless constant vigilance is maintained and control actions employed. A recent publication with numerous illustrations describes 32 important nursery disease problems of forest trees in the United States. This in-



formation will assist nurserymen, foresters, extension pathologists, and others in identifying, evaluating and controlling the diseases encountered in forest nurseries. —RM(492,492).

198. *Phomopsis* blight, caused by *Phomopsis juniperovora*, is the most damaging disease of junipers in Great Plains nurseries. The fungus forms orange-red crystals in agar cultures and the main constituent of these crystals has been identified as a tetrahydroanthraquinone compound, altersolanol A. Whether this compound is involved in the infection process can now be investigated because it can readily be identified by spectroscopic methods. —RM(516).

199. The relatively low quality of sugar maple in the hardwood forests of Minnesota has not been explained and there is no known preventive for this condition. Annual cankers, which are common and increasing in number, apparently are not of pathogenic origin. Timber cruisers and mill operators in the State should be aware of these hidden defects and should assume that they probably will be more numerous in the future. —NC(466).

200. Several conifer foliage diseases have been disseminated widely in the Northern and Northeastern States by movement of infected seedlings from nurseries to plantation sites. Inadvertent shipment of diseased materials has often occurred because seedlings infected with some diseases are difficult to detect in the spring when most stock is lifted and shipped. Information has been developed to facilitate detection and control of some of these diseases. Nurserymen and plantation managers can minimize spread and practice control of foliage diseases in that area by following recommended procedures. —NC(485).

201. Dwarf mistletoe causes a very serious killing disease of conifers but the method whereby new infection centers become established is unknown. Birds and other animals have been found to carry dwarf mistletoe seeds on feathers or fur and thus are believed capable of serving as vectors for this organism. Forest managers in the North and West should recognize the potential for establishment of dwarf mistletoe infection centers in healthy stands especially along the routes of migratory birds. —NC(465).

202. *Rhizosphaera* needlecast has been found for the first time in blue spruce Christmas tree plantations in the upper Midwest. Infected trees suffer defoliation and branch mortality beginning at the base of the tree and progressing upward. Fungicide treatments have been developed to control this problem. Nurserymen and plantation managers can limit losses in the affected area by following appropriate recommendations. —NC(486,571).

203. Changes in trees induced by disease or other factors can be measured by changes in enzyme activity. New or improved techniques have been developed to detect protease and dehydrogenases and to increase the length of time during which they can be studied after having been collected. Plant pathologists, biochemists, and geneticists in all regions now can work with these materials and may continue their experiments over longer periods of time with no significant loss of accuracy. —NC(456,499,500).

204. Brown spot needle disease causes damage to Scotch pine Christmas tree foliage. Through life history studies, the period of spore dissemination and infection has been documented and chemical and cultural control measures can now be timed so as to be most effective. By following recommended procedures, Christmas tree growers in the North Central States will be better able to limit damage in their plantations. —NC(509).

205. Insects or environmental stresses can defoliate hardwood trees, but even repeated defoliations are rarely the sole cause of tree mortality. Evidence obtained in the Northeast indicates that the root rotting fungus, *Armillaria mellea*, contributes to the death of defoliated sugar maple trees and that the ability of the fungus to infect was influenced by when and how often the trees were defoliated. Forest managers in that area can expect occurrence of *A. mellea* in stands that have been under stress and can deduce the previous occurrence of stress when mushrooms of this fungus are found. —NE(512,513).

206. Urban trees suffer diebacks and declines which are often initiated by environmental stresses. These stresses can result from air pollution, defoliation, addition of chemicals, and changes in moisture or temperature. Following the stress period, innocuous organisms may cause serious damage. A summary of various diagnostic and preventive techniques has been prepared to help city foresters and urban planners in the Midwest and Northeast to better manage urban trees. —NE(464).

207. Various injuries predispose trees to dieback and decline and to attack by biotic agents, but reasons for such predisposition are unclear. Starch levels in roots of sugar maples defoliated in Connecticut were lowered more than in roots of trees that were defoliated and girdled or those that were severed from the stump. It has been concluded that carbohydrates are moved upward in the phloem (and to a lesser extent in the xylem) of defoliated stems. Tree pathologists and physiologists now have additional information to help explain relationships between trees and various agents which adversely affect them. —NE(487,505).

208. In north central New York, white pines planted to reforest abandoned farms develop cankers if injured by ants, snow, or ice. A similar situation has developed in Maine where white pines have been planted as natural snow fences on farms along the interstate highway system. Snow and ice damage was greatest in rows oriented perpendicular to winter winds. Forest managers and land planners should avoid use of white pine for reforestation of open lands, natural fencerows, or shelterbelts in the extreme North. —NE(462,463).

209. Some of the materials present in the bark of trees affect the ability of fungi and insects to penetrate and establish themselves within. To determine the role of some of these materials in excluding insects and fungi, the concentration and seasonal variability of phenol-bound sugars were examined in five species of deciduous trees of eastern forests. It was concluded that these sugars do not change markedly with the season. Forest pathologists will use this knowledge in formulating new hypothesis for additional investigation of disease and insect problems. —NE(488,489).

210. The relative vigor or health of trees is thought to be best when starch content of roots is highest. However, starch content is difficult to determine even in the laboratory. A relatively simple method has been developed to enable determination of starch contents of roots in the field. Researchers and foresters can use this technique in working with oaks and sugar maples in the Northeast. —NE(477).

211. Pecan bunch is a widespread and serious disorder of pecan and native hickories that results in tree decline and reduced nut production in eight southern States. Although formerly assumed to be caused by a virus, recent research suggests that a mycoplasma-like organism is associated with diseased trees. This association suggests that mycoplasmas rather than viruses may cause many yellows-type diseases of forest trees and that these problems may be controllable by

proper use of tetracycline antibiotics. Forest managers in the South will benefit if a technique for controlling these diseases can be developed. —NE(503).

212. Prevention or control of wood decay in living trees is dependent upon developing a better understanding of the steps, processes, and microorganisms involved. Indications are that a regular succession of organisms is responsible for decaying wood, and if one could disrupt this succession, the process may be stopped. Also, it may be possible to prevent damage by introducing other organisms to exclude those that cause damage. Some evidence suggests a common mold fungus can exclude decay-fungi from becoming established in tree wounds for up to 1 year in the Northeast. More work must be done to clarify the principles related to wood decay and to develop practical control recommendations. —NE(496,504,506,507).

213. Concentrations of microelements that are present in wood inhibit the growth of some microorganisms while others are not affected. Five common wound-invading organisms isolated from discolored portions of northeastern hardwoods grew well in the presence of high concentrations of manganese, calcium, zinc, and iron. The ability to tolerate high mineral concentrations may enable these fungi to be aggressive wound-invaders while the growth of other, less tolerant, species is inhibited. Basic researchers dealing with the initiation and development of wood decay will use this information in developing new concepts and research proposals. —NE(508).

214. Mycorrhizae are symbiotic associations between plant roots and fungi that are essential to survival of many trees and shrubs on forest and urban sites. Among many benefits to the plant from such an association is protection from some disease-causing organisms. The various types of protection and the mechanisms involved have been reviewed. Foresters, nurserymen, and plant pathologists everywhere should be aware of the extent and limits inherent in this form of biological protection and be able to modify management practices according to existing conditions. —SE(447,478).

215. Production of containerized seedlings has uncovered many problems with tree roots and several of these involve establishment of mycorrhizal associations with various fungi. The subject of mycorrhiza has been reviewed and the relationship between production of container stock and mycorrhizal root systems considered. Nurserymen and land managers who are involved with containerized seedlings should be aware of the role of mycorrhizae in seedling production and establishment. —SE(479).

216. Identification of individual fungi that grow in association with tree roots has been very difficult. A new technique involving use of highly specific antibodies has been developed to differentiate various ectomycorrhizal fungi that occur on tree roots. Scientists and nurserymen throughout the country should be able to reliably differentiate preferred ectomycorrhizal fungi from wild types for better growth in nurseries and forests. —SE(502).

217. Fusiform rust currently causes serious damage to pines in the Southern United States. However, pine species native to the Western United States, such as ponderosa, Monterey, and Jeffrey, were found to be highly susceptible to fusiform rust in artificial inoculation studies. In addition, California black oak was susceptible and could serve as an alternate host. Because the natural ranges of these western pines and oak overlap, this rust might become established in the West if introduced into that area. Forest managers and nurserymen should screen stock imported from the South to prevent in-

troducing fusiform rust into the Western United States. —SE(453).

218. Canker-rot fungi cause degrade and cull in southern hardwoods, especially red oaks. The fungi that cause damage are distinguished from numerous others that cause heartrot by their ability to kill the cambium and induce cankers. The cause, symptoms, hosts, and damage attributable to them have been described. Forest managers in the southern States now can take appropriate action to minimize losses caused by these fungi. —SO(480,481).

219. The search for organisms that might be useful in biologically controlling forest pathogens or biodegraders continues even though success in the past has been minimal. A fungus that apparently parasitizes sporophores of the lignicolous fungus, *Peniophora tamaricicola*, was recorded from Arizona. Parasitism was not proven, but the species was described as new and was named *Platygløea mycophila*. A determination that *P. mycophila* actually parasitizes its host would be justification for using this fungus in biocontrol tests. —FPL(452).

220. Decay fungi cause millions of dollars in losses in living trees, logs, and slash in American forests, and it is important that we know as accurately as possible the names of the organisms involved. Three new North American species in each of two genera, *Laeticorticium* and *Phanerochaete*, were described in detail from sporophores and cultures. Studies clearly indicated that *Laeticorticium* could be separated into the two genera, *Ol Dendrocorticium* and *Dentocorticium*. The worldwide species in the genus, *Tomentella*, were described in a single monograph. These results will aid mycologists and forest pathologists everywhere in the study of decay fungi. —FPL(451,470,471,472).

221. Analytical procedures must be used to distinguish between closely related living organisms that coexist in ecosystems. The chemical, syringaldazine, which had previously been noted to detect the enzyme, laccase, with great specificity in cultures of lignicolous fungi, was found to be satisfactory for testing sporophores and wood in the field. Methods to eliminate interference by two other enzymes, tyrosinase and peroxidase, were elaborated. A dark brown pigment that develops in sporophores of one wood-rotter after application of a base was also partially characterized chemically. Definitive tests for three enzymes can now be conducted by scientists and technicians at the site and time of collection anywhere in the world for more reliable definition of the fungi decaying wood and the action each takes. —FPL(457,467).

222. To predict outbreaks of the Douglas-fir tussock moth, it is necessary to study the outbreak cycle in its entirety. However, this is very difficult because infestations are rarely detected until populations have increased to damaging numbers. Data were collected annually (1967-1971) from an isolated population in a mixed conifer forest (Douglas-fir, white fir, ponderosa pine) in Arizona. The outbreak cycle was defined and correlation analysis showed that density of small larvae accounted for a large proportion of the annual change in population density. Local infestations developed largely from resident populations rather than from long-range spread. Entomologists in the West can predict more accurately the development of future outbreaks of tussock moth and make recommendations for control. —PNW(352).

223. Both potentially damaging and beneficial insects breed in forest residues and the question of whether these residues should be treated remains unresolved. A review of insects associated with forest residues shows that many treatments would reduce some insect pests but might also destroy certain



beneficial insects. Researchers must clarify the role of insects in forest residue management before treatment techniques can be developed. —PNW(363).

224. Christmas tree plantations often are fertilized to improve growth and color but the effect of this practice on insect populations was unknown. Seven-year old Douglas-fir in the Pacific Northwest had increased numbers of Cooley spruce gall aphid eggs and higher winter survival of aphids after nitrogen fertilization. However, 2 years after fertilization the aphid populations were essentially the same in treated and untreated trees. This indicates that Christmas tree growers can continue fertilization of Douglas-fir without concern about increasing aphid numbers. —PNW(362).

225. The Sitka spruce weevil attacks terminals of Sitka spruce and seriously affects growth and form of this tree along the coast of Oregon and Washington. Fifteen years of study on the susceptibility of 10 spruce species and hybrids to the weevil showed that Lutz spruce (a natural Sitka-white spruce hybrid from Alaska) grows well in Oregon and Washington and its susceptibility to weevil attack is about 1/10 that of Sitka spruce. Forest managers will be able to use Lutz spruce as a replacement for the heavily-weeviled Sitka spruce. —PNW(361).

226. Sampling populations of defoliating insects requires knowledge concerning leaf populations on host trees. Research in Oregon and Washington showed that total needle populations on young Douglas-firs can be estimated by regression analysis. It was also found that a life table model in the general format used by actuaries is a suitable format for evaluating needle occurrence, mortality, and age distribution. It is visualized that these techniques will be useful throughout the country for sampling leaf feeding insects and evaluating their impact. —PNW(359).

227. Previously undescribed organisms associated with important tree species should be described to aid future workers in identification and evaluation of the role of these organisms in the ecology of the tree. A new species of mite was found infesting the bark of grand fir in Oregon. The male, female, and deutonymph of this species was described and illustrated. This information adds to the knowledge of potential pests infesting grand fir. —PNW(360).

228. Correct identification of insect viruses is essential to properly evaluate and use these materials for control of insect pests. The approved general nomenclature for most insect viruses is listed. While some of these genera may also contain viruses of vertebrates, it is significant that the genus *Baculovirus* appears to have no association with vertebrate viruses. This is an important factor in evaluating the safety of these viruses as microbial control techniques, and entomologists throughout the country will benefit from this information in developing microbial control techniques. —PNW(391).

229. The spruce budworm, *Choristoneura* species, represents the most damaging group of coniferous forest defoliators in North America. Field screening techniques conducted in British Columbia and Oregon, established (E)-11-tetradecenyl acetate, and (E)-11-tetradecenal as the principal sex pheromone components for *C. viridis* and *C. biennis*, respectively. These findings are of major importance in the development of detection survey techniques and environmentally safe control procedures for these budworms. —PNW(377).

230. Understanding the biology of parasites is important to being able to predict population changes of important forest pests. Reproduction of two important parasites of Pacific Northwest forest insects was severely impaired at 100 percent

R.H. but was quickly restored when they were transferred to 62 percent relative humidity. This suggests extended periods of high humidity may contribute to temporary reduction of parasite numbers and permit an expansion of the pest population. This information will be useful in developing models to predict trends in forest pest populations throughout the country. —PNW(375).

231. Although parasites have a significant role in regulating populations of the large aspen tortrix, the natural parasites of this important aspen insect are relatively unknown. In Alaska, 24 species of parasites have now been described and information on their biologies is provided. This reference material will enable entomologists and others to assess the role of these parasites in the dynamics of tortrix populations in that area. —PNW(390).

232. The natural enemies of larch casebearer, which causes serious growth reduction in western larch, do not exist in the Western United States where this insect was first found in 1957. *Chrysocharis laricinellae*, an important European parasite of this insect which has successfully controlled larch casebearer in the Eastern United States, has been introduced into the West. An established population of the parasite now has been reported in Idaho. If *C. laricinellae* continues to spread, it may provide forest managers with an effective control for larch casebearer in the Pacific Northwest. —PNW(376).

233. The larch casebearer, which causes serious growth reduction in western larch, is difficult to control because it is not exposed to biological or chemical control agents in its leaf mining stage. Studies in southeastern Washington showed that most larvae reached the more vulnerable casebearing stage between September 11 and October 25 and thus fall releases of parasites to control casebearing larvae should be delayed until after mid-September. This information will help forest managers in the Pacific Northwest select control options for the larch casebearer more effectively. —PNW(374).

234. The European pine shoot moth is an introduced forest pest which is becoming increasingly important to pine nurseries, plantations, and ornamental trees in the Pacific Northwest. Opportunity for development of survey and control methods is increased by chemical identification of the sex pheromone of this insect as (E)-9-dodecenyl acetate. Availability of this pheromone is expected to be very helpful in permitting entomologists and others to conduct surveys and develop control programs throughout the Northern United States where this insect occurs. —PNW(380).

235. Locating pertinent literature is critical to identifying forest insect pests. The three volumes of the catalog for the Hymenoptera of America north of Mexico are very important bibliographic and systematic sources on hymenopterous insects, but the third volume, or 2nd supplement, of the catalog had no host index. A host index has now been prepared. Citations include both plant and animal host associations and the pages where they can be found. This index should greatly facilitate the identification of parasitic Hymenoptera and sawflies throughout the Nation. —PNW(389).

236. Study of defoliating insects in both interior and southeastern Alaska revealed an apparently undescribed insect parasite in the genus *Pygocryptus*, and others were found by examining specimens in private, university, national, and foreign collections. Taxonomic study yielded two previously described holarctic species, four new species, and three new subspecies. Diagnostic keys and descriptions of the new species and subspecies are presented. This work may aid in future population and biological control studies of defoliating insects in Alaska. —PNW(388).

237. Investigation of the effect of sex attractants on insect behavior is dependent upon a full understanding of the basis and nature of odor response in insects. During the winter, both sexes of the beetle *Ips pini* showed a marked decline in respiration and in the response to both male frass and standard extracts of frass which contain the attractant. The results indicate a physiological change in overwintering beetles that may be a form of hibernation. This research provides the information needed by researchers in the North and West to standardize the assays used in the chemical identification of *Ips pini* attractants. —PSW(326).

238. A method must be devised for manufacturing the materials which affect behavior before insect populations can be managed with an insect-produced attractant. Part of the synthesis of brevicomin, the aggregating attractant of the western pine beetle, has been accomplished. This brings us one step closer to a practical control method for western pine beetle in California, Oregon, and Washington. —PSW(349).

239. Identification of pathological factors that predispose white fir to bark beetle attack is prerequisite to developing a risk rating system for selective cutting. Measurement of xylem sap tension in California white fir showed that heavy dwarf mistletoe infections increased moisture stress in upper boles and this condition was associated with high incidence of fir engraver beetles. White firs with dwarf mistletoe infections must be considered high risk, and forest managers should have them removed from the stand to prevent a buildup in fir engraver population. —PSW(340).

240. *Ips paraconfusus* is a serious pest of western pines when large populations build up in logging slash. Control procedures for this insect are lacking although work with sex lures shows promise. One of the compounds of the aggregation pheromone complex may be produced by a bacteria, *Bacillus cereus*, in the gut of the insect. This discovery opens new avenues to manipulating populations of bark beetles throughout the country. —PSW(327).

241. The mountain pine beetle causes high mortality to several species of pine in the western United States. A competing risks analysis has been used to evaluate the importance of various mortality factors on mountain pine beetle populations. This technique may be useful in predicting population trends of the mountain pine beetle and in indicating factors which might be manipulated to effect control. —INT(332,333).

242. Radiography has been used to sample populations of the western and southern pine bark beetles, but has not been tested on mountain pine beetle in lodgepole pine. In a Wyoming test to determine characteristics of mountain pine beetle populations, radiography and the standard bark removal technique gave comparable estimates of live beetle numbers. However, radiography is more costly, and the causes of beetle mortality usually cannot be determined. In addition, beetle populations in radiographed areas were adversely affected, probably because of drying of wood and bark, which resulted in erroneous estimates, of brood survival and distorted sex ratios. For those reasons, the radiographic method is not recommended for sampling mountain pine beetle populations. —INT(322).

243. Little is known about the biology of *Pityophthorus confertus*, a bark beetle which commonly infests decadent western pines and which occasionally causes mortality in healthy ponderosa pine. Infested billets of lodgepole pine from Idaho were brought to the laboratory to study brood development; information obtained will prove very useful in future population and control studies of this insect. —INT(321).

244. The white fir needle miner has caused serious defoliation and mortality of white fir in the Southwest. Descriptions of this insect and its life history and habits are assembled. Possible control strategies are discussed. With this information, forest managers in the West will be able to recognize and evaluate control options for this insect. —INT(392).

245. Little detail is known of the life history and habits of the roundheaded pine beetle, an important pest of ponderosa pine in the Southwest. Field studies in New Mexico have now documented the periods of adult beetle emergence and attack, and of brood development. This information will be useful to researchers and field workers alike in enabling them to better understand the ecology of the roundheaded pine beetle in Southwestern forests. —RM(350).

246. Lodgepole terminal weevil is common in interior forests in the Central Rocky Mountain and Intermountain areas. Sometimes its impact on infested stands causes concern to land managers. An analysis of situations in Colorado and Idaho showed that even where heavy infestations occur, long-term effects are not generally expected to be severe if the forest is managed for production of poles or sawlogs. Even light infestations would hinder production of quality Christmas trees. This information should better enable managers to assess the importance of infestations occurring on their lands in terms of resource management objectives. —RM(387).

247. The impact of roundheaded pine beetle outbreaks on ponderosa pine stands in the Southwest has not been well understood. Data are now available on changes in stand density, species composition, tree size, and related factors following a beetle outbreak in south-central New Mexico. Land managers will use this information to make better decisions about what action to take, if any, when an outbreak occurs. —RM(386).

248. Population studies of the southwestern pine tip moth in Arizona required estimates of fecundity. A good correlation was found between pupal size and potential number of eggs. This information, combined with knowledge of other factors affecting egg-laying success, can be used to estimate fecundity, an important factor determining population trends. —RM(347).

249. Ponderosa pine trees successfully and unsuccessfully attacked by mountain pine beetle have several symptoms in common, so that diagnosis is not always easy. Guidelines now available will enable field workers to correctly distinguish nearly all successfully attacked trees. This will prevent removal of uninfested trees and make control operations more efficient. —RM(356).

250. Temperature is a major physical factor affecting bark beetles, but often the parameters for activity and development are unknown. In laboratory studies in Colorado, mountain pine beetles attacked logs, mated, and constructed egg galleries at 4.4°C, but no eggs were deposited in 6 weeks. Activity of adults and growth rate of larvae increased with increase in temperature. Knowledge of responses at the lower thresholds of activity is important to applied work leading to better control methods. —RM(355).

251. Survey methods for spring cankerworm egg masses are needed to predict defoliation and the need for control in Great Plains shelterbelts. The moths commonly deposit inconspicuous egg masses in crevices on the branches or trunks of Siberian elm trees. In field studies in North Dakota, egg masses were found also in old pupal cases of *Rogas*, a parasite of cankerworm, and in bark lesions caused by several diseases attacking host trees. Knowledge of these exposed oviposition sites will make it easier to make egg counts when cankerworm populations are at a low level. —RM(384).



252. The spring cankerworm is an important defoliator of Great Plains shelterbelts. Sometimes epidemic populations of cankerworms remain high even when all foliage on the host trees has been consumed before the larvae completed their development. Observations in North Dakota indicated that larvae dropped from the trees, fed on flax in adjacent fields, and continued their development into the pupal stage. Survival of the insect on unusual host plants may explain maintenance of high population levels of spring cankerworms. —RM(385).

253. The pinyon needle scale is a native sapsucking insect of the Southwest that occurs primarily on single-leaf pinyon. Information on its life history, distribution, ecological relationships, and control has been summarized. This information will enable forest managers in the Southwestern States to identify and control pinyon needle scale on their lands. —RM(357).

254. Spiders prey on insects, and documented records describing different predators and prey are helpful in delineating the ecologies of both groups. Crab spiders were found feeding on two genera of scarab beetles resting on pine trees in Arizona. These new records of prey, spider-habitat associations, and predators of scarab beetles extend our knowledge of relationships in forest ecosystems. —RM(348).

255. Little information has been available about the long-term effects of spruce beetle outbreaks, many of which seemed devastating at the time. Current stand conditions in western Colorado were evaluated 15, 25, 50, and 100 years after spruce beetle outbreaks had occurred. In general, adequate regeneration had resulted except in areas that had been heavily salvage-logged. Species composition was altered in favor of fir, which is expected to persist for many years, but eventually be overtaken by spruce. Land managers facing spruce beetle losses now have some insight into what long-term effects are likely from the outbreak. —RM(378).

256. Nematodes are recognized as important factors in bark beetle ecology, but information about them has been scattered, scanty, and generally difficult to obtain. A monograph is now available summarizing the current state of knowledge about these organisms and describing 32 parasites and 112 associates, many new to science. Bark beetle specialists now have at hand a comprehensive and up-to-date review of this important group. —RM(353).

257. Nonpesticidal control techniques are desirable to minimize damage by the Saratoga spittlebug in red pine plantations. The most critical stage in the spittlebug's life cycle is when it hatches from the eggs that are on pine buds, searches out suitable host plants, on the forest floor, and covers itself with masses of spittle before it starves, desiccates, or is captured by predators. Normally 85 percent emerge between 0700 and 1100 hours; peak emergence is between 0800-0900 hours. Emergence is somewhat prolonged on cool, cloudy, or misty days. This information, plus other biological data, is necessary to develop pest management techniques for this important Lake States conifer plantation pest. —NC(395).

259. Adult jack pine tip beetles injure jack pine shoots and may deform trees in the Lake States. A wasp-like parasite causes significant beetle mortality during the second stage of larval development. This parasite was the only major mortality-causing factor and was responsible for 15 to 40 percent of the beetles' total mortality. The importance of the parasite suggests further study to determine its effectiveness as a regulator of jack pine tip beetle populations and damage. —NC(343).

260. A mixed larch provenance planting in Michigan was damaged by a little-known larch moth. The moth damaged

shoot tips of eastern larch and several varieties of Japanese larch. Early larvae are leaf miners; older larvae are free feeders. Two generations per year occur in Michigan. Sufficient information is now available to test chemical suppressive techniques on this insect. —NC(366).

261. One potential method of minimizing damage to red pine plantations by the Saratoga spittlebug is to significantly reduce the growth of sweet fern, an alternate host of the spittlebug. A new species of moth whose larvae feeds on sweet fern has been described and studied. The moth has one generation per year and locally may severely damage sweet fern. Although this moth is common, it does not exist in numbers sufficient to significantly reduce the growth of sweet fern. —NC(393).

262. One potential method of minimizing damage to red pine plantations by the Saratoga spittlebug is to significantly reduce the growth of sweet fern, an alternate host of the spittlebug. Moth eggs were collected from sweet fern and the resulting larvae were reared and studied in the laboratory. This basic study is a necessary preliminary to assess the potential of biological control of sweet fern. —NC(394).

263. Population studies of the forest tent caterpillar require the ability to identify the sexes from as many life stages as possible. Previously, sex identification was only possible by examining the moths' antennae. Now, the position and size of the pupal genital opening is known to be a dependable diagnostic character. Entomologists concerned with population changes of this insect and other moths will find this technique useful. —NC(367).

264. If birds are to be considered an important predator of the jack pine budworm, they must be able to regulate their predation in response to variations in prey abundance. Predation by three common summer resident birds—black-capped chickadee, brown-headed cowbird, and chipping sparrow—was studied in response to ninefold variations in budworm populations. Bird predation showed little or no change over the wide range of budworm intensities. Therefore, bird predation probably will not be an important factor regulating jack pine budworm abundance, unless budworm densities are at low or endemic levels. —NC(354).

265. Moths of the family Tortricidae are a destructive but taxonomically confused group. The nomenclature of one group of these moths has been significantly simplified and one new species has been described. One moth species was found to vary significantly in size with elevation of capture—increased size coinciding with increased elevation. The updated and simplified nomenclature will greatly benefit all researchers working with this economically important group of insects. —NC(358).

266. The gypsy moth is one of the most destructive pests of forest, shade and orchard trees in the Northeastern United States. Analysis of data which was accumulated for 20 years in New England confirms that defoliation is most likely to occur in stands which have more than one-half of the overstory composed of oaks, gray and paper birch, or aspen. However, egg mass density is not related to overstory composition. This knowledge is essential to developing a rational approach to management policies that will prevent outbreaks of the gypsy moth. —NE(328,329).

267. Forecasting gypsy moth defoliation is difficult because insect density does not necessarily reflect amount of subsequent defoliation. A multiple-regression model developed from Massachusetts data reflects statistically significant correlations between defoliation by the gypsy moth and a series of biotic and physical variables. The results suggest current

criteria for control may lead to treatment of populations that would have caused little defoliation if left untreated. Those responsible for managing gypsy moth populations should evaluate their criteria for control action in light of this new information. —NE(330).

268. The ability to predict airborne spread of young larvae from parent population centers is essential to developing predictive capability for outbreaks of gypsy moths. A mathematical model was developed that predicts larval dispersal and identifies critical biological and physical factors that affect dispersal capability. Field verification of this model will provide a means for improving ability to predict gypsy moth spread in the Northeast. —NE(351).

269. Prior to developing the nucleopolyhedrosis virus (NPV) of the gypsy moth for control of this destructive defoliator on northeastern hardwoods, it was necessary to identify the most virulent strain available from many geographical sources. The most promising NPV's available were assayed and the strain with most virulence was identified. This strain is now being developed and tested for use in a gypsy moth management system. If effective, this will be a welcome addition to the techniques now available for gypsy moth control in the Northeast. —NE(372).

270. During a disease diagnosis study, it became necessary to develop a dissecting dish that could be sterilized and reused. Such a dish was prepared using a silicone encapsulant. Because the silicone can be autoclaved and will remain rubbery from 65°C to 250°C, it can be reused many times for pathological studies. This dish will have wide application when dissection of small animals is necessary. —NE(368).

271. Regression analysis, a commonly used analytical method for examining variables in a data set, can be very expensive if the number of variables is large. A method was developed which examines all possible regressions with a minimum of arithmetic and shows which subsets of variables are most important without examining all subsets. This method has wide application in research and it is being incorporated into the widely used biomedical package of statistical computer programs. —NE(341).

272. Dutch elm disease has spread throughout much of the United States since it was first introduced here in 1930, and during that time considerable effort has been expended to develop techniques for reducing the mortality caused by this fungus. Techniques now being tested include various procedures for limiting the population of the beetles which spread the fungus from diseased to healthy trees. If these procedures prove to be effective and become operational, they will have widespread application throughout the country for control of this disease. —NE(324,325,412,413,418).

273. For management of insect populations by sterilization techniques we need to determine the ratio of sterile to fertile males required to cause population decrease. A previously developed population model was examined to mathematically demonstrate the parameters necessary for the population to become extinct. This research will have national application in the development of those insect control procedures which utilize the sterilization technique. —NE(383).

274. Although insects seriously damage cones and seeds in southern pine seed orchards, we do not know what insects are most damaging to specific hosts at specific periods of conelet development. First-year flower and conelet losses, which accounted for the greatest reduction in seed yields, were due to seedbug and loopers on loblolly pine and seedbugs and tip moths on shortleaf pine. Major causes of second-year cone losses were coneworms, midges, and pineshoot borers. These

findings will permit the establishment of meaningful priorities for future research and the development of control methods to minimize future losses. —SE(336).

275. Seedbugs are known to reduce seed production in southern pine seed orchards, but the nature of conelet damage was unknown. Second-instar nymphs caused 100 percent conelet abortion when confined to shortleaf pine conelets in a Georgia seed orchard for 4 days. Feeding was confined almost exclusively to the cytoplasm of nucellar tissue in developing seeds or ovules. This knowledge will be used to more effectively time chemical control applications and to develop systemic insecticides which should minimize seedbug damage in southern pine seed orchards. —SE(335).

276. The decline of seed yields in Southeast pine seed orchards has perplexed orchard managers for several years. Caging experiments and work with radiographs has demonstrated that seedbugs are responsible for much of the damage. Protected loblolly pine cones yielded 2.5 times as many filled seed as did cones exposed to natural bug populations and shortleaf pine cones yielded 12 times as many full seed as did uncaged ones. Seed orchard managers and entomologists will use this knowledge to develop control techniques for these insects. —SE(334).

277. Germination of slash pine seed harvested from some southern seed orchards is much lower than that harvested from the wild. Radiographic and microscopic examination of slash pine seed showed that many which appeared full by standard cracking procedures were actually seedbug damaged. Those seed lots in which extensive molding occurred during germination tests possessed greater numbers of seedbug-damaged seed. These observations implicate seedbugs as the major cause of the decreased germination and associated moldy condition of slash pine seed, and provide more evidence of the need for controlling seedbugs in southern forest tree seed orchards. —SE(373).

278. Coneworms drastically reduce yield of pine seed in southern seed orchards, and effective alternatives for control are needed. In a Florida study, larval feeding was stimulated by acetone extracts of slash pine cones and recombined fractions of the extracts. Stimulation also was induced by sugars from slash pine cones. Researchers can use this information to develop techniques using baits and repellents to control coneworms. —SE(337).

279. The fall cankerworm, which commonly defoliates maples, oaks, and hickories over extensive areas in the southern Appalachians, could not be reared in the laboratory to provide a supply of eggs to study an important egg parasite, *Telenomus alsophilae*. A successful method of rearing successive generations of fall cankerworm on cut foliage has been developed. When fully developed, this rearing method should supply ample fall cankerworms for biological studies of parasites. —SE(364).

280. The southern pine beetle is a very important killer of pine in Honduras, but its population trends cannot be predicted until insect associates, including parasites and predators, are determined. Thirty species of insect associates of the beetle were identified in Honduras. Nine genera were known biological control agents. Clerids and ostomatid beetles were in sufficient number to control bark beetles. This information will assist future workers in the study of population dynamics and biological control of the southern pine beetle in Honduras and possibly in the southern U.S. as well. —SE(331).

281. Studies of parasites to control the elm spanworm, an important defoliator of hardwoods in the southern Appalachians, depend on maintenance of a properly scheduled supply of



spanworm eggs in the laboratory. The first successful artificial diet for rearing elm spanworm through a complete generation has been developed. While modification of the diet and rearing technique is needed to increase survival, the method holds promise as a means of obtaining a continuous supply of the elm spanworm eggs for biological control research. —SE(338).

282. Mortality of pine seedlings on cutover lands is significantly increased by weevils, but information on weevil development was lacking. Tests have shown that the time required for development from egg to adult emergence ranges from 3 to 15 months, depending on date of oviposition and location. As a result, planting should be delayed one full year to avoid weevil damage on areas harvested in the southern Appalachians during the summer and also on areas harvested anytime after June in the Piedmont and Coastal Plains. Areas harvested before June in the Piedmont and Coastal Plains can be planted the following winter. This knowledge will help forest managers in the Southeast schedule harvesting and planting activities so as to minimize weevil damage in subsequent stands. —SE(382).

283. The introduced pine sawfly, *Diprion similis*, periodically causes defoliation and mortality of pine in Northeastern United States. The parasite, *Monodontomerus dentipes*, is very important in the control of *D. similis* populations. Information on the systematics, morphology, hosts, distribution, and life history of this parasite is reported. This information should be of great help to future workers who seek to employ this parasite against *Diprion* and *Neodiprion* sawflies. —SE(339).

284. The southern pine beetle develops poorly when symbiotic fungi are absent; yet, the nutritional role, if any, that fungi play in the beetle's development is unknown. A tenfold weight increase occurred between the beetles' egg stage and the subsequent inner bark larval stage when fungi were present. There was also a fivefold increase in the beetles' lipid content while feeding on fungus laden phloem. Recognizing that the fungus-phloem substrate apparently contributes to the lipid requirements of the beetle is an important consideration in future nutrition and rearing studies. —SO(323).

285. The nutritional requirements of the southern pine beetle and its associated fungi are unknown—a problem which exacerbates the rearing and subsequent research on this important insect. A higher percentage of short-chain fatty acids occurred in host-attacking adults than in host-emerging adults. Presumably, attacking beetles feed on the inner bark and synthesize new fatty acids while making galleries. The egg-laying stage, therefore, may also be an important nutritional stage, a requirement which will significantly aid further nutrition research on this important insect. —SO(346).

286. The mites that feed on bluestain and other fungi found in bark beetle-attacked trees are numerous and difficult to tell apart. The proper identification of these mites is essential to properly assess their role in influencing southern pine beetle populations. *Tarsonemus krantzi* was described as a new species. It had previously been confused with two other closely related species that coexist with it. This information permits continuing research on the potential use of mites as biological control agents for the southern pine beetle. —SO(379).

287. There are no known effective biological control agents for the southern pine beetle. Fifty-seven species of mites associated with the beetle in Central America and Mexico were collected and identified. Twenty-six species do not occur in Louisiana and at least nine of these are known predators of the southern pine beetle. With further study, some of these mites may be candidates for importation into this country as

biological control agents of the southern pine beetle. —SO(365).

288. Toxic baits used in Latin America to control leaf-cutting ants do not give consistently good results. Generally, the attractant used in the baits, a trail-laying and trail-following chemical (pheromone), is attractive to a variety of these ants. Yet ants of at least one economically important species do not respond to the bait, presumably because they use a significantly different trail pheromone which must be identified and synthesized. Once the newly identified attractant is incorporated into the toxic bait, tropical foresters and agriculturalists will have an effective and highly selective method of minimizing defoliation by these ants. —SO(371).

289. At least two species of ants can distinguish the optical isomers of an ant alarm pheromone. One isomer is at least 100 times more potent than the other. In future pheromone research, the pheromones will have to be checked not only for chemical purity but also for optical purity if the pheromones are to work at optimum efficiency. Periodic difficulties with field tests of various attractants (pheromones) suggested the possibility that some insects can distinguish different optical configurations (isomers) of the same compound. —SO(369,370).

290. The carpenterworm causes considerable loss through defect and degrade to oaks and other hardwoods. An annotated bibliography of the carpenterworm including 206 references and covering all technical literature through 1972 was prepared. It should be useful throughout the U.S. and southern Canada to foresters, entomologists, pest control and extension personnel, students, and others who wish to refer to the literature on carpenterworm. —SO(381).

#### Pest control techniques

291. *Diplodia pinea* severely damages pines that are over 30 years old in plantings in the Great Plains. Effective and economical control measures for this disease have been lacking. Most of the infection of new shoots of Austrian pine occurs from the time buds open to just before needles emerge from needle sheaths. Bordeaux mixture, the fungicide, applied once during this period of development reduces infection 51 percent and two applications reduce infection 87 percent. Arborists following this spray schedule obtain good control of *Diplodia* blight on pine stems in eastern Nebraska. —RM(522).

292. *Lophodermium pinastri* needlecast disease has caused damage or mortality to millions of red and Scotch pines in nurseries and Christmas tree plantations in 17 States and three Canadian Provinces. Techniques for recognizing, detecting, and controlling this disease have been developed. Growers in northern and eastern United States and adjacent portions of Canada will be able to minimize losses by implementing the recommended procedures. —NC(521,523).

293. Scleroderris canker continues to cause serious losses in red and jack pine plantations and nurseries in the North Central and Northeastern United States. During a 3-year period, the fungicide, chlorothalonil, was more effective in controlling this disease than the previously recommended maneb and ziram, and it required fewer applications per year. Nurserymen and plantation managers now have an effective, registered fungicide for use in controlling Scleroderris in these areas. —NC(525).

294. Douglas-fir beetle is the most important pest of Douglas-fir in western Oregon and Washington, where this tree species produces one-fifth of the Nation's supply of sawtimber. A beetle-produced chemical, methylcyclohexenone (MCH), which effectively inhibits attraction of beetles to

breeding materials, was tested in downed Douglas-fir and Sitka spruce trees in western Oregon. Two granular slow-release formulations reduced attack briefly in Douglas-fir and for 5 weeks in spruce. Practical use of this highly selective nontoxic chemical appears to be feasible for control of these destructive beetles especially if the rate of release from granular formulations can be improved. —PNW(417).

295. Information on methods for testing and evaluating microbial pesticides is very limited. A variety of techniques for evaluating *Bacillus thuringiensis* formulations and the spray equipment to be used for aerial application have been developed. This information could be applied throughout the United States wherever microbial insecticides are used to combat defoliators such as gypsy moth, Douglas-fir tussock moth, and spruce budworm. —PNW(408,410).

296. The pales weevil (*Hylobius pales*) is the most serious pest of pine reproduction in the eastern United States. The contact toxicity of 38 insecticides to adult pales weevil was determined to serve as a guide for selecting alternatives to aldrin and DDT. Several compounds were more active than either of these two materials. Recent field experiments by others using some of the more promising candidate insecticides have resulted in the registration of carbofuran and chlorpyrifos for the protection of newly-planted pine seedlings against weevil damage. —PSW(415).

297. Adoption of new techniques for sampling and controlling forest insects depends on successfully demonstrating efficacy in large-scale tests. The first successful operational use of attractants to suppress a forest pest has involved work with the western pine beetle in a ponderosa pine forest of California. With this necessary and difficult step accomplished, the use of attractants nears the fully operational stage. —PSW(398).

298. The synthetic pyrethroid, resmethrin, shows promise as a highly effective and environmentally safe insecticide, but data on environmental chemistry, which is needed for registration, is lacking for forest sites in the western United States. Residues of resmethrin were analyzed on three kinds of foliage and from water samples after aerial application of 0.05 and 0.15 lbs. per acre. After 7 days, no residue could be found on aspen and Douglas-fir; on willow, less than 0.05 ppm were detected. No residue was found in water samples. These data will be useful in evaluating the suitability of using resmethrin as an insecticide to control forest pests in the United States. —PSW(396).

299. The oak leaf roller (*Archips semiferanus*) periodically causes severe defoliation and sometimes death of oak in the Northeast. Contact toxicity tests of four insecticides (pyrethrins, bioethanomethrin, mexacarbate, and phoxim) against the larvae were conducted as a preliminary step in finding alternatives to DDT for control of this pest. All four candidate insecticides were highly toxic to the leaf roller, causing 90 percent kill with a dosage of less than 1 ug/insect. This research identifies highly promising candidates worthy of further development. —PSW(403).

300. The spring cankerworm (*Paleacrita vernata*) is a pest of shelterbelts and also defoliates forest and shade tree hardwoods throughout much of eastern North America and locally as far west as Colorado, Texas, and California. Laboratory tests of 11 insecticides were conducted to find more effective candidate insecticides. Bioethanomethrin, resmethrin, pyrethrins, phoxim, and mexacarbate were more toxic than carbaryl, the reference chemical. This research identified potential candidates with high toxicity and environmental safety, which warrant further development as chemical suppression tools for spring cankerworm. —PSW(411).

301. The cherry scallop-shell moth (*Calocalpe undulata*) defoliates wild and choke cherries over much of eastern North America, and there is presently no registered insecticide for use against this insect. The contact toxicity of 10 insecticides was evaluated as a guide for the selection of candidates for field testing. In a comparison of the insecticide response of this insect and four other forest geometrids, pyrethroids were always the most toxic and malathion the least toxic. Other researchers seeking to develop control recommendations for this insect can select from the several candidate insecticides that were identified as having sufficient potential to warrant further evaluation. —PSW(416).

302. There are presently no registered insecticides for aerial suppression of the Douglas-fir tussock moth, which periodically causes severe defoliation and killing of Douglas-fir over extensive areas of Oregon, Washington, Idaho, and other western States. Field tests were conducted with mexacarbate, trichlorfon, carbaryl, and bioethanomethrin against the tussock moth in Oregon to evaluate their efficacy in killing larvae and protecting foliage. Formulations were applied by helicopter to replicated plots up to 500 acres in size. Results were inconclusive although all four candidates showed enough potential to warrant further testing. —PSW(426).

303. There are presently no chemicals registered for use in the aerial suppression of the pine butterfly *Neophasia menapia* which periodically reaches epidemic levels in ponderosa pine stands and causes up to 90 percent mortality in the Western United States and Canada. Aerial application of 0.15 and 0.30 pounds per acre of mexacarbate in Montana reduced populations 97 percent. *Bacillus thuringiensis* provided a 73 percent reduction at 0.5 pound/acre and 92 percent, an evaluation of defoliation effects. These tests provide the data needed for planning pilot control projects to further develop these materials for control of the pine butterfly. —PSW(399).

304. Effective, environmentally-acceptable control methods are needed to protect high-value Douglas-fir forests from the Douglas-fir beetle. A repellent-type of pheromone, methylcyclohexenone (MCH), reduced beetle attacks on down logs by 96 percent in Oregon, Washington, and Idaho. These findings established MCH as potentially useful in pest management systems for the Douglas-fir bark beetle in both coastal and interior Douglas-fir forests. —INT(402).

305. Outbreaks of spruce beetle have killed several billion board feet of spruce in northern and western parts of the United States during this century. In Idaho, the natural antiaggregative compound of the Douglas-fir beetle, methylcyclohexenone (MCH), suppressed the attraction of spruce beetles to spruce logs by 99 percent. This success in modifying spruce beetle behavior justifies further work with MCH to develop control strategies for this insect. —INT(405).

306. The Douglas-fir beetle is an important killer of Douglas-fir in many areas of the West, and satisfactory techniques for controlling this insect are lacking. The "confusion strategy" which involves area-wide application of the Douglas-fir beetle attractant Douglure to confuse and disperse beetles was tested in Idaho. The method shows promise for reducing damage, but the intervals between baited trees must be reduced to disperse the beetles over more trees. This information will permit more effective additional testing of the "confusion strategy" for the Douglas-fir beetle. —INT(414).

307. A severe outbreak of mountain pine beetle is currently underway in the Front Range of the Colorado Rockies, and elsewhere in the region. The cause is probably related to the



presence of large areas of susceptible forests. What to do about it depends on land managers' objectives. Researchers and pest control specialists propose combined programs of suitable control methods. —RM(423).

308. Cacodylic acid has potential for bark beetle control, but timing of application has been a difficult problem. The results of field tests in Colorado indicate that the material can be usefully applied to ponderosa pine during a brief period following mountain pine beetle attack. Careful timing of applications will enable users to obtain optimum results with the control method. —RM(422).

309. Pinyon needle scale is a pest of pinyon in a variety of situations in the Southwest. A noninsecticidal control method using a stream of water to wash eggs off infested trees was found effective in field tests in New Mexico. The method has excellent application potential in urban areas where impact of the pest is often most severe. —RM(400).

310. The pine tip moth stunts the growth and renders unsightly several pine species in the Great Plains, but residual contact insecticides frequently have not provided adequate protection. In field tests in Nebraska, carbofuran or phorate at 10 lb./acre in the nursery or 2 oz. per inch of trunk diameter in the soil around ornamental and windbreak trees gave good protection. Carbofuran or dimethoate sprays also worked well in nurseries and plantings, but timing of dimethoate application was critical. Systemic insecticides can provide good long term control of this very damaging insect. —RM(419).

311. Freshly planted red pine seedlings are vulnerable to injury by white grubs and other agents. Seedling mortality by white grubs accounted for 24 percent loss over a 5-year period when not chemically treated. Less than 4 percent of the aldrin-treated seedlings were lost to white grubs. Aldrin has no obvious effects on the nongrub mortality agents as canker diseases, root rots, and J-rooting caused as great or greater mortality in aldrin-treated plots as in the untreated plots. Although aldrin significantly reduced white grub-caused mortality, other mortality-causing agents must be minimized to successfully establish pine plantations in the Lake States. —NC(401).

312. Parasites are often used to attempt control of new gypsy moth infestations, but difficulties have arisen with obtaining sufficient numbers of healthy parasites when needed. A new radiographic procedure permits observing and quantifying the development and mortality of parasites. This technique will permit screening to assure using only viable parasites for field release. Persons responsible for controlling gypsy moth populations throughout the country will benefit from this new information. —NE(409).

313. Management of gypsy moth populations has involved using several techniques to control their numbers, among which is the application of the bacterium *Bacillus thuringiensis*. A newly developed high-potency strain of this bacterium has shown considerable promise for controlling gypsy moth. A large three-State test proved the operational feasibility of using this material and was the principal source of information for its registration for aerial use against gypsy moth. Persons with gypsy moth control responsibilities in the Northeast will benefit from availability of this technique. —NE(406,427).

314. Field testing of new toxicants against the gypsy moth is necessary to expand the chemical diversity of control programs. Helicopter applications of Gardona failed to control this insect. Treatment failed because: (1) The wettable powder formulation did not adhere to the foliage; (2) the test area experienced above average precipitation after spraying; (3) the spray deposit and residue were highly variable, and (4) the

chemical lacked sufficient toxicity against the target insect under field conditions. Gardona is not considered a suitable chemical for gypsy moth spray programs. —NE(397).

315. The pales and pitch-eating weevils are the most important insects in first-year pine plantations in the eastern United States. A laboratory bioassay using wafers of elder pitch was used to evaluate 28 compounds as feeding deterrents for pales weevil. Fourteen of the compounds which significantly deterred feeding were then bioassayed by measuring the amount of feeding on pine twigs dipped in the compounds. Carbaryl, Benlate, mexacarbate, and Dexon were sufficiently promising as feeding deterrents to warrant field testing. This information will aid researchers in formulating future research to minimize more effectively losses from these damaging weevils. —SE(424).

316. Orthene is a relatively safe systemic insecticide which might be useful for the control of pine reproduction insects but data on distribution and metabolic fate within the treated plant were lacking. Chromatographic and radiochemical analyses show that Orthene was absorbed rapidly from nutrient solution and distributed through 130-day-old loblolly pine seedlings within 1 hour after treatment. Orthene was converted to its primary metabolite, Monitor, and an unknown compound which were insecticidally active against adult pales weevils. Orthene should be considered as a candidate for field tests of insecticides to control pine reproduction insects throughout the country. —SE(425).

317. To design a selectively toxic chemical insecticide one must exploit biochemical differences between insects and mammals. Work with the insecticide dimethoate has shown how modification of chemical structure can increase toxicity. An extension of this research with materials to control the southern pine beetle will, if successful, be of benefit to forest land managers in the South. —SE(404).

318. In the southern United States, pales and pitch-eating weevils can cause up to 90 percent seedling mortality in plantations established on recently harvested pine lands. These weevils can be controlled with silvicultural or chemical techniques. Information on these techniques has been made available in popularized form. This information will be very helpful to southern forest managers and private landowners who need to control weevils on their pine lands. —SE(421).

319. Forest managers have been puzzled for years by the intermittent recurrence of southern pine beetle outbreaks in certain areas of the West Gulf Region. Five years of data from 2,960 chemically treated infestations indicated a tendency for infestations to recur in high-density, pure pine sawtimber. In the last 4 years, 29 percent of the spots was associated with lightning strikes. Results will be used by researchers in the development of a stand risk/hazard rating system for the southern pine beetle. —SO(407).

320. Eighteen States have enacted legislation which regulates the activities of the structural pest control (SPC) industry whose services cost homeowners about \$200 million annually, but neither these laws and regulations nor their efficacy have ever been analyzed and compared. In several States, legislation appeared to improve SPC services, but the marked lack of uniformity and reciprocity of existing legislation suggests that a model SPC law, developed by responsible interested parties, could be worthwhile. Because the content, enforcement, and uniformity of regulations determine their value, and because all States will pass legislation in response to the Federal Environmental Pesticide Control Act, this report should be of value to the SPC industry, State regulatory agencies, EPA, and indirectly to the homeowner. —SO(420).

321. Anthracnose leaf spot is the most serious disease affecting black walnut. In a test of eight fungicides applied to a young plantation in southern Illinois, Benlate 50W was most effective in reducing leaf spotting. When this chemical becomes registered, it can be used by land owners to protect walnut plantings. —NC(822).

#### Pest management strategies

322. There is considerable debate among foresters and pathologists as to the importance of dwarf mistletoe infections on the boles of ponderosa pine. In a study conducted in Colorado, it was found that infections on boles 5 inches in diameter or larger are generally of low vigor and, consequently, are not likely to cause infection on surrounding trees. To control the disease, the forest manager need not remove large trees with bole infections or those with bole infections plus prunable light branch infections. —RM(526).

323. Fusiform rust deforms, degrades, and kills pines throughout the South. Landowners with high incidence of rust may suffer more damage than they realize. Infected slash pine stands have been examined and management recommendations formulated for various levels of infection. Forest managers in South Carolina and Georgia can now appraise and react to their own situations more accurately. —SE(527).

### Improving the Water Resource

#### Water quality

324. Baseline water quality data from undisturbed areas are necessary for assessing impacts of land management practices. In a relatively undisturbed area of the Wasatch Mountains of Utah, suspended sediment was found to be negligible and chemical quality excellent. However, bacterial load indicated some pollution by warm-blooded animals despite exclusion of livestock and minimal presence of man. —INT(150).

325. Nutrients and sediment are subject to removal from forest lands following timber harvesting, with possible adverse effects on forests and water. At Hubbard Brook in New Hampshire, deforestation and growth repression with herbicides for 3 years caused minor increases in particulate content (sediment) of streamflow the first 2 years and a 15-times increase the third year. Dissolved substances increased the first 2 years and returned to previous levels about 4 years after cessation of herbicide applications. Results suggest that a forest ecosystem can recover rapidly following deforestation while minimizing the effects of erosion. —NE(148).

326. Impacts of forest clearcutting on water quality are a continuing source of concern. In a West Virginia study, 78 acres of hardwoods were conventionally clearcut on an 86-acre watershed. Effects on water temperature, pH, turbidity, and dissolved solids were negligible the first 2 years. There was a temporary increase in nitrate nitrogen and phosphate, and a decrease in calcium and sulfate. Success in avoiding damage to water quality was attributed to careful road management, retention of a forest strip along the stream, and rapid, lush vegetative regrowth after clearcutting. —NE(147).

327. Because quality can rarely be determined for entire bodies of natural water, samples must be relied upon to estimate these data. This paper reviews where, when, and how to sample; frequency, size and contamination of water samples; and some of the mechanics of handling them. Sampling procedures should be considered in the planning stages of any water quality study. —NE(146).

328. Increased concern over groundwater contamination has created the need for new, improved methods of collecting data. A sampler was developed for obtaining water samples at predetermined depths. The sampler permits determination of gradients of contaminants in a groundwater system. —NC(152).

329. Finely divided logging debris may reduce the oxygen level in forest streams. Water from a typical Oregon Coast range stream was sampled and tested for biochemical oxygen demand (BOD) of the debris. The BOD of leaf material exposed to fluctuating temperature exerted a 5-day BOD 4.0, 2.4, and 4.2 times greater than the standard temperature BOD<sub>5</sub> for Douglas-fir needles, western hemlock needles, and red alder leaves, respectively. This study will be useful in developing a predictive model for management of forested lands for water quality. —PNW(153).

330. Finely divided logging debris may seriously reduce the oxygen level in forest streams. Management recommendations have been formulated as a result of research in the Pacific Northwest on the problem. Unless suspended above ground, logs should not be yarded across streams. Slash should be kept out of streams. Slash which enters an important fish stream should be removed quickly. These guidelines are important for maintaining high quality stream habitat for fish and aquatic organisms. 1. —PNW(154).

#### Water yield and timing

331. Effects of differences in water use by pine and hardwoods on streamflow have been hypothesized, but, until recently, were unmeasured. Fifteen years after two experimental watersheds in the southern Appalachians were converted from a mature deciduous hardwood cover to white pine, annual streamflow was reduced about 20 centimeters (20 percent) below that expected for the hardwood cover. Managers now have documentation that substantial changes in streamflow will occur when hardwoods are converted to pine. —SE(129).

332. Effects of land uses or treatments on water infiltration and runoff are not adequately recognized in land use planning or management. Studies reveal hydrologically better soil conditions under forest cover as compared to cultivated or grazed areas on the same soil type. Findings indicate that land managers should consider the importance of the hydrologic consequences of land use decisions. —PSW(111).

333. Current methods of forecasting streamflow from melting snowpacks are inadequate to meet needs of modern hydroelectric power plants. The profiling isotope snow gage has resulted in more accurate determination of beginning of snowmelt in the Columbia River Basin. Proposed procedures should result in more accurate forecasts of streamflow. —PSW(102).

334. A better understanding of the behavior of snowpacks is essential to effective management of water resources. Soil temperature was found to have no effect upon midwinter and spring snowmelt. Water moves through and from the packs each month of the winter. Forest management practices can influence snowmelt timing and thus the time of delivery of water to streams. —PSW(125).

335. Free water (liquid phase) content of snow varies as timber cover is changed. A measurement system is needed wherein profiles of free water content may be periodically determined under different timber cover conditions. A system is under study in which microwave and gamma sources and detectors positioned opposite one another yield profiles of den-



sity and liquid phase water content of the snowpack. With both density and free water profiles available, the condition of the snowpack can be accurately determined and, when combined with meteorological information, useful predictions can be made regarding the melting and water discharge rates from snowpacks. —PSW(103).

336. Land managers need a method of predicting the amount and location of additional solar light reaching the forest floor as a result of timber harvest. The amount of sunlight and heat reaching the surface is affected by shadows cast by surrounding vegetation. A technique and a computer program and tables have been developed for calculating the extent of boundary shading for any combination of date, slope, and aspect. This information can also be used to predict changes in stream temperature and snow accumulation or ablation. —PSW(81).

337. Timber cutting to increase water yield may pose a threat to water quality. In New Hampshire, water yields during normally low summer flows were increased an average of 11 acre inches per year from a deforested watershed and about 1.5 acre inches per year from a watershed where one-third of the timber was cut in parallel strips. Nutrient release and sediment were greatest in the deforested watershed. Nutrient losses after recent commercial clearcuttings in the White Mountains were intermediate between the deforestation and strip-cut treatments. Municipal watershed managers should weigh these results when forest treatments are considered. —NE(91).

338. In order to manage forests in the northeast for increased water yield, we need more information about forest evapotranspiration and how it is altered by land management practices. In a strip-cut forest in New Hampshire, opening and closing of leaf stomata was observed as an indicator of transpiration. Results suggest that a single large clearcut will reduce evapotranspiration more and provide greater water yield increase than cutting the same forest area in a number of smaller blocks. —NE(67).

339. An inexpensive soil-water sampler that uses a miniature porous ceramic cup and a surface storage container was designed. The new sampler eliminates field transfer and permits immediate preservation of the sample. It can be enclosed to discourage vandalism. —NC(85).

340. Availability of soil water is a major factor affecting transpiration, but little is known about the effects of this factor on Northwest conifers. Under decreasing water potential, transpiration rates of ponderosa pine, lodgepole pine, Douglas-fir, grand fir, and Engelmann spruce seedlings were measured. At a potential of -10 bars, transpiration rate of the pines was only about 12 percent of their maximum rate. The transpiration rate of firs was 27-37 percent of maximum. Spruce was intermediate in response. From a watershed standpoint, pines should be more economical users of water than species less responsive to soil drying. —PNW(105).

341. A portable instrument for rapidly determining thermal conductivity of liquids and solids has been adapted to measurement of snow density. Measurements can be directly calibrated from the known relationship between snow density and thermal conductivity. Readings made in a few seconds compare favorably with the customary thermal conductivity analysis in which a time-temperature relationship developed over many minutes is normally required. —PNW(71).

342. Lodgepole pine is being harvested in small patch cuts which may have a favorable influence on water yields. Small clearings in Wyoming forests affected the pattern of snow distribution but not the total amount of snow in the area. Melt

rates in the clearing were about twice those in the interior forest zones. The differences in snow accumulation and melt must be considered when evaluating the effects of timber harvests on snowpacks and water yield. —RM(78).

343. Land managers need a comprehensive report which will bring them up-to-date on the effects of pinyon-juniper control on multiple uses. A status-of-knowledge report substantiates that: (1) Mechanical methods of pinyon-juniper removal are not likely to increase water yield; (2) removal of pinyon-juniper overstory by herbicides can increase water yield; (3) there has been no statistical verification of changes in flood peaks or water quality due to treatment; (4) herbage yields increase after virtually all pinyon-juniper treatments, but potential livestock carrying capacity varies greatly due to differences in plant composition; (5) the response by deer to these treatments is, on the average, neutral; (6) the more successful conversion projects just about break even from a benefit-cost standpoint under 1972 economic conditions. —RM(55).

344. Feasibility of increasing water yield by removing deep-rooted brush and replacing it with grass depends on how much water can be produced and how conversion affects other resources. If treatment areas are kept small and interspersed with brush, water yield and forage for livestock are increased while wildlife habitat and esthetic values are preserved. Over the long run, conversion should reduce erosion by reducing or eliminating the heavy erosion cycle set off by periodic wildfires in unmanaged chaparral. —RM(90).

345. The effect of vegetation type conversion on water yield varies with density of the shrub cover and precipitation. Two small watersheds typical of sparsely covered brush fields were treated with herbicides to test the effect of conversion on water yield and erosion. Annual streamflow was increased slightly. Sediment yields were decreased due to the stabilizing influence provided by increased grass and forb cover. Data from this study suggest that changing vegetative cover from brush to grass is probably not justified because of the low return in water yield. —RM(94).

#### Managing, rehabilitating, and improving watersheds

346. Planting and seeding of denuded areas often fail because of inadequate or excessive rainfall. A method was developed for Utah and other Intermountain States utilizing a representative rainfall record and an analytical smoothing procedure. A reliable method of estimating the probability of consecutive rainless days will help avoid future planting failures. —INT(64).

347. Bedrock plays an important role in determination of quality and quantity of streamflow. Bedrock influences water yield through its effect on deep seepage, interbasin transfer, and storage and release of water. Chemical and physical characteristics of bedrock influence nutrient cycling and erosion rates, which in turn influence water quality of streams and lakes. —INT(110).

348. One of the major remaining problems in establishing pine on eroded areas of the southern Coastal Plain is to improve first-year survival on droughty soils. This problem was studied in northern Mississippi by testing the effect of two transpiration retardants on survival, height growth, dry matter accumulation, and water use of loblolly pine seedlings. Height growth was unaffected by the chemicals, but root and needle weights were less than those of the controls after one growing season. Seedlings treated with retardants and then subjected to drought conditions survived no better than the untreated seedlings. —SO(108).

349. Although water quality is the most pressing immediate problem in the South, quantity of water from forest land is also important in land use planning. Management of hardwoods for sustained yield can increase water supplies by 0.5 to 2 acre-inches annually. Conversely, anticipated conversions from hardwood to pine in the South could reduce available water supplies. Protection or improvement of hydrologic performance of forest soils will become an important element of forest land use planning. —SE(61).

350. Reliable estimates of discharge are needed for selecting proper culvert sizes and for designing bridges. Discharges for several intervals of flood recurrence were developed for forested drainages in western North Carolina. Tables for several types of culverts are presented for ease of selecting proper culvert size, provided discharges are known. Flow values allow greater accuracy in estimating flood discharge and more economy in design of structures to carry flood water. —SE(60).

351. The determination of surface area and biomass of trees per unit area of land is needed in order to understand the flow of energy, nutrients, and water through forest ecosystems. Measurements and procedures used to estimate surface area and biomass were compared for a 10-year-old white pine stand. Stratified two-phase sampling gave the best estimates of three methods tested. The results are being used in evaluating the influence of the forest on streamflow and the cycling of elements through the forest. —SE(130).

352. The amount of solar irradiation reaching a mountain slope is an important parameter for describing the climatology of the slope, but actual data are not easily obtained. This publication shows that, without onsite measurements being made, the intensity of solar radiation on mountain slopes can be determined. It can be estimated by using slope factors derived from tables and measurements of global solar radiation on a horizontal surface, provided the measurements are for similar cloud and atmospheric conditions. This estimation method has application for land capability mapping and for use in snowmelt, evapotranspiration, and plant growth models for mountain land. —SE(133).

353. Surface area of foliage in a hardwood stand is an important parameter in assessing transpiration and photosynthesis. An optical planimeter for measuring leaf area of broadleaf species is described. This instrument is easy to use, compact and portable, and is capable of measuring leaf areas for a variety of species. —SE(80).

354. Basic information is needed on substances causing water repellency in certain soils of the Southwest. Litter burned over a column of sand produced water repellent substances of important chemical nature. Both polar and nonpolar substances moved into the underlying sand during burning. After burning, heat moved downward, fixing the more polar hydrophobic substances. The less polar substances revolatilized, broadening the water repellent layer. Temperatures over 250°C were required for fixing and revolatilization. The study provides information to achieve goals directly applicable to watershed management problems. —PSW(120).

355. Almost all good reservoir sites in California have been occupied, so it is important to preserve the capacity of present reservoirs. Depositions in 48 northern California reservoirs were quantitatively related to watershed, streamflow, snow frequency, and land use variables, including 10 different classes of roads. Streamside location of roads caused the most sedimentation, twice that of other locations, with improved secondary roads near streams being the greatest contributor. Differences in sedimentation associated with roads give plan-

ners a quantitative basis for choosing among alternative locations and designs of roads in forest areas. —PSW(46).

356. Meltwater from the snowpack may be the source of important nutrients for vegetation, soils, streams, and lakes. These chemical inputs were estimated for snowpacks in the White Mountains of New Hampshire. The snowpack, just before spring melt, contained about 50 percent of the total calcium and 25 percent of the total nitrate and sulfate measured during the winter precipitation period. Potassium stored in the snowpack just before melt was nearly twice that measured in the incoming winter precipitation. Nutrients stored in the snowpack accounted for less than 10 percent of the amount lost in spring streamflow. A better understanding of the nutrient cycle will help in managing forests to sustain soil and water productivity. —NE(92,93).

357. Public resistance to certain timber harvest practices has stimulated a search for logging methods more acceptable to the public. The CHUBALL, a cable logging system, and URUS, a portable skyline system from Austria, were tested on the Fernow Experimental Forest in West Virginia. The tests were brief, but it appeared that environmental values are protected during timber harvest by these methods. Further tests, particularly economic studies, are needed before the systems will be fully accepted by commercial loggers. —NE(79,139,141).

358. European larch is a promising species for planting old fields in the unglaciated portion of the upper Mississippi Valley. Observations suggested that its thick litter mat may shed rainfall that could contribute to floods. Further study indicated that larch litter did shed some rain but not enough to be of significance. —NC(118).

359. Livestock grazing is a common practice on steep slopes of the upper Mississippi Valley's unglaciated region. Heavily grazed pastures are a major source of floods. Their contribution to floods drops sharply soon after cessation of grazing, however. Runoff from two small, open pastured watersheds was similar; but by the third year after cessation of grazing on one watershed, runoff had dropped sharply. After 3 years without grazing, a heavy mat of bluegrass blanketed the ground, and the soil was much looser. —NC(119).

360. Relating trout habitat and biological responses to sediment sources and sediment discharge is dependent on measurement of total sediment movement. A method of using sills for sampling total sediment load in streams was developed. The method permits measurements of bedload in addition to the more commonly suspended sediment component. Field data indicated that the "sill samples" probably provided better measurements of total sediment discharge than traditional "stream samples" do. —NC(82).

361. In managing watersheds, it sometimes becomes necessary to remove deposits of sediments in streams. Sedimentation basins are an effective way of trapping and removing bedload sediments. As a management aid, guidelines have been developed for using sedimentation basins in streams. —NC(83).

362. Large natural gas and petroleum pipelines that cross forested wetlands often block normal water flow, raising the water table on the upslope side. The high water table significantly reduces tree growth or even kills the trees. In north-central Minnesota, such damage has been prevented on the Chippewa National Forest by excavating ditches during pipeline construction to provide the necessary cross drainage. —NC(50).

363. Peat deposits in watersheds of the Lake states have been considered as natural regulators that maintain stream-



flow during summer months. Recent studies have shown that most streamflow from peatland occurs in the spring, and distribution of flow is not significantly different from mineral soil watersheds. Except for groundwater bogs, peat and bog lands release water too slowly to maintain streamflow during dry summer seasons. Peat deposits may provide temporary short-term storage to reduce storm flow runoff peaks after summer drying periods when bog water tables are low. —NC(47).

364. Information on water and its use in Alaska has been scattered and fragmentary. Consequently, a summary was made of the characteristics and distribution of surface waters in southeast Alaska. Data on the quality and quantity of the water resource are evaluated. Present utilization of the resource is described, and recommendations for its future protection are outlined. A section on further research needs is included. —PNW(121).

365. Almost no history exists of watershed research in the North American subarctic. Basic data on parameters, such as precipitation and runoff, are scarce; consequently, the framework for environmental understanding is very weak. A multi-agency, multi-disciplinary basic research program for the most significant subregions of central Alaska is being developed to rectify this situation. —PNW(124).

366. The species composition of soil microfungus populations in adjacent stands of red alder; Douglas-fir; hemlock, and Sitka spruce; and a mixed alder-conifer area were strongly correlated with the dominant vegetation type. Ninety-two microfungus species were isolated. The population in soils of mixed alder-conifer vegetation was intermediate between those of pure alder and pure conifer. There was little difference in microfungus species composition among soil horizons within a stand. —PNW(142).

367. Management of forest residues in the Pacific Northwest has potentially significant impacts on soil and water resources. Residue management influences soil and water resources in proportion to the amount it increases soil disturbance. Burning forest residues increases the quantity of chemicals that may reach streams, roughly in proportion to the quantity of fuel burned. Broadcast burning after logging of old-growth Douglas-fir increased loss of nutrient cations 1.6 to 3.0 times that from an unburned area. —PNW(116).

368. Almost every year, fires burn many acres of valuable forest land in the West; in 1970, wildfire destroyed vegetation on the Entiat Experimental Forest in north central Washington where hydrologic measurements began in 1959. During the second post-fire year, record precipitation triggered debris avalanches which destroyed two stream gaging stations. Measured runoff at the remaining station was 360 percent of the annual maximum during calibration. Effects, if any, of road building and logging on the watersheds were probably minor compared with effects of fire and subsequent record precipitation. —PNW(88).

369. The pine-forested Black Hills of South Dakota are an important water-yielding area, both for surface flow and ground-water recharge. The area is an island of forest and flowing streams in the broad expanse of the relatively dry northern High Plains. Available knowledge is synthesized in an in-depth appraisal which provides guides and criteria for what can and should be done to assure good management of the water resources in the Black Hills. —RM(112).

370. Avalanches are common in many mountainous areas and often threaten lives and damage property. With the tremendous increase in back-country use and second-home developments, it is important that people know how to recognize potentially dangerous sites. Avalanche-prone sites have

been described and illustrated and a checklist given to help evaluate field evidence of avalanche activity. —RM(107).

371. It is difficult to predict failure of snow slab and the onset of avalanches. Tensile strength of snow varies with volume of the sample. An equation is presented that predicts tensile strength as a function of snow density for snow volumes of 1 to 10 cubic meters. Previous strength relations were mostly derived from much smaller sample volumes; small samples should be avoided when determining strength of snow. —RM(126).

372. The effects of increased snowfall due to cloud seeding on the major forest types in the Southwest is generally unknown. In New Mexico, the growth rate of spruce in an area of deep snow accumulation was compared to growth rates in an area receiving about 75 percent less snow cover. The comparison suggests that weather modification programs in the Southwest will have little detrimental effect on the annual or long-term radial growth of existing spruce forests. —RM(76).

373. Land managers must be aware of the multiresource options available to them as the demand increases for more and different mixes of services. Simulation models have been developed to predict changes in snowmelt and yield of water and timber resulting from timber harvest. Hydrologic changes and timber yields can be estimated for various lengths of time. Land managers can use the model to project changes in snowmelt and water yield and in timber growth and yield subsequent to timber harvest in lodgepole pine and spruce forests. —RM(100).

374. Conflicts between land use and the environment in the subalpine forest zone cannot be resolved without objective multiresource analysis, which accounts for both primary resource responses and their interactions. A simulation model has been developed to determine the longterm interaction between water and timber resources with regard to different silvicultural systems. The model can also evaluate the effect of road construction on erosion and sediment yields. The land manager can simulate the probable hydrologic changes resulting from different timber harvesting practices for both short and longterm planning intervals. —RM(101).

375. Research on controlling blowing snow in southeast Wyoming suggests that new engineering criteria for snow fences promise to improve the economy and performance of snow fence systems for other applications as well. Snow control systems can be designed that are unusually effective in preventing drifts, improving visibility, and reducing the formation of road ice. —RM(134).

376. Land managers now have a summary of what is known about the hydrology of big sagebrush lands and how this knowledge can be applied to accomplish management objectives. Climate, soils, vegetation, snow accumulation, and water yields are reviewed; how management practices alter vegetative composition and the hydrologic regime is also discussed. The practice of converting sagebrush lands to other herbaceous vegetation may result in a maximum of 15 percent increase in water yields. Potential for increasing water yields appears to lie in reducing evaporative losses of windblown snow. —RM(128).

377. Fourwing saltbush has been difficult to establish for erosion control and range rehabilitation in the Southwest. Mycorrhizal fungi may play a role in growth of these plants in New Mexico. Innoculation with a known endomycorrhizal fungus tended to stimulate growth. These findings provide additional guidelines for the establishment of fourwing saltbush by artificial means. —RM(144).



378. Pinyon and juniper trees have often been removed in an attempt to improve forage production and water yield, although little has been known about the actual effects of this practice in the southwest. Felling of a 13 percent cover of alligator juniper in north-central Arizona resulted in a 38 percent increase in total herbage production and a 45 percent increase in forage plant production. This shows that forage response is rather minimal when open alligator juniper stands are removed indicating that such continued practice merits reassessment. —RM(54).

379. Snow surveys to estimate snowpack water equivalent on large basins are currently uneconomical. A technique was developed to effectively estimate water equivalent of the snowpack from aerial photographs. On sites where forest stands and slopes are variable, only topographic features need to be measured. Attributes of the forest overstory must also be measured on more homogenous sites. This technique has been used by the University of Arizona and Salt River Project to forecast runoff from watersheds in Arizona. —RM(98).

380. Forest managers must estimate costs of thinning and piling projects to insure proper budgeting and expenditures of funds. A regression model was developed to predict thinning and piling costs as a function of the degree of timber basal area removed. Costs of thinning are related to basal area removals, including commercial logging. The model is being used in additional economic research studies and for timber management operations. —RM(137).

381. Opportunities for increasing water yields and other multiple use values on ponderosa pine lands have been the subject of much research in Arizona. A status-of-knowledge report describes multiple use productivity on watershed lands. Yields of timber, herbage, and water under past management and under new experimental land treatments are reported, along with information about effects on wildlife values; esthetics, flood and sediment hazard, and water quality. This report provides land managers with summarized, current information to evaluate proposed land management practices. —RM(51).

## Forest Resources Evaluation

### Resource inventories

382. The decade of the 60's saw some dramatic changes in use and management of Rocky Mountain forests. A sharp increase in demand for nontimber uses of forest land, growing public awareness of the forests' role in man's environment, and active concern for protection of that environment led to restrictions on certain uses of forest land and on the kinds of activities allowed in timber production. Timber managers' primary concern shifted from the relationship of cut and growth to the availability of forest land for timber production and the need to operate within budgetary and environmental constraints. Recent research describes the resource, the timber supply outlook, and some of the problems associated with increasing timber output from a shrinking acreage available for timber production. —INT(965).

383. Continuing periodic forest surveys of the various States are necessary to provide up-to-date information about the Nation's forest resources. Resurveys were completed in Delaware, New Jersey, Connecticut, Massachusetts, Rhode Island, Vermont and New Hampshire. Reports of these resurveys summarize the present timber situation and changes that have taken place since previous surveys. They present data on timber inventory, annual net growth, and timber removals;

and discuss trends in timber supply, timber availability, and projections of future timber supply in the respective States. —NE(957,958,963,964,972).

384. The third forest inventory of Missouri showed a commercial forest land area of 12.4 million acres in 1972, a 10.5 percent decrease from the area reported in 1959. The largest losses occurred in the prairie counties and the southwestern Ozarks. Growing stock volume increased by 5 percent to 76 million cords. Sawtimber volume increased at a more rapid rate—13 percent—to 15 million board feet. Individual reports include analyses of the timber situation and trends for various regions of the State, and provide a basis for assessing the States' contribution to the forest resources of the North Central Region and the nation. —NC(961,961,967,977,978,980,984).

385. Reports published for the southwest, southeast, and south delta portions of Louisiana show commercial forest land decreases since 1964 ranging from 5 percent in the southeast parishes to 6 percent in the southwestern and south delta parishes. Softwood growing-stock and sawtimber volumes have increased in all three geographic units, while hardwood volumes have remained about the same in some areas with decreases in others. A Statewide interpretive report will be issued when all parishes have been inventoried. These reports provide information on timber supply trends and progress of forest management in this important timber-producing State. —SO(968,969,970).

386. Almost 138 million acres, or over 70 percent of the commercial forest land in the South, qualify as southern pine sites, that is, forested uplands, excluding those growing cove-type hardwoods, that are supporting pine or show evidence of its former occurrence. More than half of these sites are dominated by hardwoods, and 50 percent of the hardwood inventory in the South is growing on pine sites. Ownership patterns, lack of capital, lack of interest and the problem of hardwood disposal have hindered conversion. New techniques of utilization may provide a market for a significant portion of the South's hardwood inventory and give impetus to converting low-grade hardwood stands to more valuable pine. —SO(976).

387. Analyses of past and current supplies of the important timber resources of Oregon and Washington have generally been published separately for geographic regions within each State. Reports published this year include totals for forest area, volume, growth, and removals as well as data for the individual regions within each State. Thus, users of this information can obtain a complete picture of the timber resource situation in each State from a single report. —PNW(959,960).

388. The first intensive forest inventory of that part of the Koyukuk River drainage lying north of the Arctic Circle was completed. Commercial forests occupy less than 5 percent of the 742,000-acre inventory unit, but, despite the northerly latitudes, support an average volume in excess of 1100 cubic feet per acre. Although generally restricted to narrow bands along drainages, commercial forests were found as far as 70 miles north of the Arctic Circle. Volumes reported for commercial forest land total 37.9 million cubic feet of growing stock and 87.8 million board feet of sawtimber. This report presents the first complete picture of the timber resource in this extensively forested survey unit. —PNW(971).

389. The fourth forest inventory of Georgia showed a decrease in area of commercial forest land since 1961. About 2 million acres were diverted to non-timber uses, but 1 million acres of new forest were added. With two-thirds of its land

area in commercial forest, Georgia has more timberland than any other State except Oregon. Volume of growing stock has increased and growth is equal to or greater than removals in all except a few counties south of the Altamaha River. Many new plantations in this area will have an impact on future growth. Statewide net annual growth per acre is the highest in the southeast. A reinventory of the Northern Coastal Plain of North Carolina also showed a decline in commercial forest land. Volume of softwood growing stock decreased, while volume of hardwood growing stock increased. Growing stock removals have increased by more than 50 percent, and softwood removals exceed net growth in 15 of the 23 counties. This is an up-to-date picture of the timber situation in these two very important timber-producing States. —SE(974,985).

390. Nonindustrial private forest land owners in the Southeast have 14 million acres which can be silviculturally treated beyond the rate already applied, and earn a 4-5 percent return. The predominant treatments are conversion of oak-pine and oak-hickory stands to pine. These investments would yield an annual increase in pine supplies of 1.3 billion cubic feet at a cost of 710 million dollars. —SE(975).

#### Utilization and production

391. Veneer log production in the Mid-South in 1972 increased to 2,287 million board feet, the North Central region produced 64 million board feet, and the Northeast region produced 125 million board feet. Softwood composed 93 percent of Mid-South production, an increase of 13 percent over the 1969 composition and continuing the trend of Southern pine plywood production which started in 1963. The Mid-South produced over 20 percent of the U.S. softwood plywood in 1972. Production and number of mills in the hardwood veneer industry in the Mid-South and North Central regions declined, following the trend of many years. Increased competition from improved panel products, competition from plastic and paper products, and decreased availability of high quality hardwood logs are all cited as reasons for the decline in the hardwood veneer industry. These statistics are essential to analysis of trends and prospective demand for timber for production of veneer and plywood in the United States. —SO(991,995,1001).

392. Oregon processed 10.4 billion board feet of timber in 1972 and California produced 5.5 billion board feet, both of which are an increase over the 1968 production levels. Sawmills process the majority of roundwood in both States, 60 percent in Oregon and 86 percent in California. Veneer and plywood production constitutes the next largest share. Most of the pulp input comes from mill residues, 98 percent in Oregon and 82 percent in California. Ninety-five percent of the wood residues in Oregon were utilized compared to 81 percent in California. —PNW(1005,1007).

393. Pulpwood production in the South (47.1 million cords), the Northeast (7.5 million cords), and the Lake States (4.5 million cords) all increased in 1973 above their 1972 levels with the Northeast showing the largest gain (29 percent). In both the South and Lake States, softwoods composed 73 percent of the production, but in the Northeast, hardwoods composed the majority with 54 percent. The majority of the production increase in all regions was hardwood, reflecting changes in pulping chemistry which permit the use of hard textured hardwoods and the relative scarcity of the softwood resource. The use of plant residues for pulpwood continues to increase in all regions, particularly in the South, where it rose 27 percent. Pulp capacity increased 5 percent in the South from 1972-1973, but only rose 1.5 percent in the Northeast. Pulp products consume about one-third of total domestic industrial round-

wood. Information on pulpwood production is important to all users of industrial wood and for analyses of the overall timber supply and demand situation in the United States. —SE(989,997,998,1000).

394. The South experienced its highest pulpwood prices ever in 1973. Hardwood prices were \$21 per cord in the Mid-South and \$28 per cord in the Southeast where pulping capacity has increased relative to the resource supply. These prices represent the largest increases on record, 20 percent in the Southeast and 14 percent in the Mid-South. In the Mid-South, the hardwood and softwood price rises were about equal, but softwood price increases in the Southeast were twice as large as hardwood increases. Information on pulpwood prices and trends reflects the relative supplies of different species and forms of raw materials, and furnishes a clue to prospective demand for these materials. —SE(988,993).

395. Forest disturbances and changes in forest areas create problems in keeping forest inventories current. Bulk multispectral scanner imagery from the Earth Resources Technology Satellite (ERTS) revealed 79 percent of the changes in forest and nonforest land, timber harvested areas, and natural disturbances in Carroll County, Georgia. Imagery for late spring and late fall are best for detecting disturbances. With some improvement in resolution, satellite imagery could be used to locate disturbed forest inventory plots and reduce ground samples for inventory updates. —PSW(1009).

#### Inventory and analysis techniques

396. Research in forest inventory sampling techniques resulted in 1) 3P sampling being shown feasible for remeasurement plots in successive inventories and 2) the development of a process using Convex mathematical programming for optimum allocation of available funds for meeting specified precision requirements on several variables. These results contribute to increased efficiency and reduced costs in measurement of the nation's forest resources. —SO(1015,1016,1022,1023).

397. Substantial acreages of California forest land are not capable of supporting the stand densities indicated by normal yield tables. Stocking capability must be determined if overestimates of production capacity are to be avoided. Equations have been developed which predict the stocking capability of five areas in California using site index, physical characteristics, and the presence of indicator plants. The equations can be used to identify areas incapable of "normal" stocking and to provide adjustments of anticipated timber yields. —PNW(1019).

398. Forest land-use planners require a broad spectrum of information upon which to base their decisions. Earth Resources Technology Satellite imagery can be helpful but is limited by spatial position errors that often exceed 500 meters and low resolution that obscures forest roads and forest damage. However, ERTS images have a potential for providing the planner a broad synoptic view of the resource base and the ability to detect and monitor small changes in the forest environment down to a 5-acre minimum. With improved resolution and improved computer classification procedures, satellite multispectral scanner data should be a valuable source of natural resource information. —PSW(1017).



## Bettering Silvicultural Systems

### Natural regeneration

399. Seed is essential for natural regeneration but seed crops are erratic in size and frequency. Seed production estimates for lodgepole pine in central Oregon over periods ranging from 11 to 22 years indicate enough seeds were produced for a satisfactory crop of seedlings 3 years out of 4 if conditions for germination and survival were favorable. Ponderosa pine produced only five good crops in 22 years. Consequently, chances for natural regeneration of lodgepole pine in a reasonable length of time are much better than for ponderosa pine. —PNW(751).

400. The yardstick used to evaluate adequacy of regeneration is critically important. Since the early 1930's, the stocked-quadrat method has served as the principal means of evaluating regeneration on cutover areas in the West. Suggestions are given on stocking standards, plot size, sampling intensity, and other factors which will improve use of the stocked-quadrat regeneration survey system. Regeneration can be adequately evaluated if the land manager follows established procedures and has sound objectives for guidance. —PNW(777).

401. It is difficult to obtain natural regeneration of lodgepole pine on volcanic soils. Seedling survival on 19 volcanic sites near West Yellowstone, Montana is positively correlated with the amount of silt plus clay in the soil and negatively correlated with total nitrogen and available potassium. Together, these three factors account for 93 percent of the variance in first-year seedling survival. These results provide a basis for predicting lodgepole pine regeneration success on a wide range of volcanic soils in and near the study area. —INT(756).

402. Prescribed burning has been suggested as one way to enhance advance oak regeneration on sites where succession favors less desirable species. One year after a prescribed burn in a 102-year-old red oak stand in southern Wisconsin, mortality of 1-year-old red oak seedlings averaged 58 percent. Because there were more than 7,000 seedlings per acre present before the burn, rather heavy initial mortality could be tolerated provided further mortality is low. However, the fire was ineffective in reducing competition from ferns and woody shrubs. These results emphasize that one prescribed fire is not sufficient to reduce competition, but additional research is needed before fire can be used as an effective tool to enhance growth of advance oak reproduction. —NC(753).

403. Harvesting mature lowland conifers often leads to the development of lowland brush. A summary publication recommends clearcutting, followed by broadcast burning of slash and broadcast seeding to regenerate most black spruce lowland sites. Research studies are underway to provide acceptable means of reproducing northern white cedar and tamarack which provide valuable game habitats. —NC(754).

404. Effective and efficient methods are needed to eliminate unwanted vegetation left after harvesting aspen in mixed stands, so that a fully stocked stand of aspen suckers can be established. The development of aspen suckers the first 8 years after felling all unmerchantable trees was more favorable than the development following prescribed burning in northern Minnesota. Although prescribed fire can effectively control residual hardwood overstories detrimental to aspen sucker growth and survival, the long-term effect of fire is unknown. Fire is recommended only when complete felling or other methods are unavailable or impractical. —NC(755).

405. Information is needed to determine whether crop trees released in young, even-aged stands respond and maintain their crown position in the stand. The response of 7-year-old red maple stump sprouts and northern red oak advance reproduction on a fair site in West Virginia showed that release had no effect on height growth of either species but did result in better diameter growth and retention of dominance of the red maple sprouts. These results demonstrate that hardwood species respond differently to release, which makes it difficult to prescribe a release for mixed hardwood stands. —NE(758).

406. Foresters need to be able to predict the size of cone crops well ahead of seedfall so they may intelligently plan for natural regeneration of stands and for cone collection. In Alabama, longleaf pine cone crops were closely related to average daily pollen counts during the flowering period. If this relationship holds for other species and in other areas, landowners and seed collectors will be able to estimate pine cone crops from pollen counts some 20 months ahead of seedfall. —SO(747).

407. Longleaf pine seedling stands under a shelterwood canopy can be severely damaged when the overstory is harvested. A central Alabama study showed that logging-related seedling mortality is less if the overstory is removed when seedlings are 1 or 2 years old than if they are newly established or over 2 years old. Managers should schedule final removal cuts so that areas having lightly-stocked seedling stands can be logged at the optimum time. —SO(748).

408. How prescribed fires affect established longleaf pine seedlings in stands being regenerated by the shelterwood system is not clearly understood. In an Alabama study, mortality of grass-stage longleaf pine seedlings from prescribed winter burns was much greater under an overstory than in openings, and declined as root-collar diameter of seedlings increased or brown-spot needle infection decreased. In clearcut openings burned 2 or more years after logging, seedlings 0.3 inch in root-collar diameter or larger usually survived. Using results of this study, land managers can decide if advantages or prescribed fire in grass-stage longleaf pine outweigh potential losses. —SO(749).

409. Pine seed crops cannot be estimated accurately from cone counts until the number of full seeds per cone is determined. An Alabama study showed that longleaf pine seeds develop sufficiently by August to permit seed yields to be estimated from counts of full seeds exposed by bisecting cones longitudinally. By applying these results, foresters can gain additional valuable time to plan for cone collection, seedbed preparation, and other silvicultural operations that require prior knowledge of the potential seed crop. —SO(750).

### Silvicultural methods

410. Regeneration of clearcuts often is difficult in the South Umpqua Basin in Oregon. Research has provided equations which relate the success or failure of regeneration or clearcuts to soil depth, soil texture, elevation, solar radiation, moisture, and temperature of the preharvest environment. This new procedure will help South Umpqua land managers determine whether or not to clearcut given stands. —PNW(766).

411. Natural reproduction has proven satisfactory for regenerating most large-scale clearcuts in southeast Alaska, but some problem sites have been identified. Alluvial stream terraces are often taken over by alder and salmonberry while steep unstable slopes are more prone to land slides following clearcutting. Clearcutting is the best silvicultural system for southeast Alaska forests, but alternative systems should be



used on problem areas where clearcutting is incompatible with other resource values. —PNW(767).

412. Effective shelterwood regeneration requires knowledge of seedling development. Two years after shelterwood cutting of true fir-mountain hemlock type in the Oregon Cascades, mortality of grand fir was 70 percent and mountain hemlock was 90 percent. Results show that an overstory basal area of at least 80 ft<sup>2</sup> should be kept for satisfactory fir regeneration and probably more than 100 ft<sup>2</sup> should be maintained if mountain hemlock is an important component of a stand. —PNW(775).

413. Lodgepole pine literature is found in many different journals and miscellaneous publications, making it difficult to determine what information is available. A new proceedings summarizes the ecology, management, productivity, and utilization of this important western conifer. It also includes a partially annotated bibliography of over 1100 references. This compilation of up-to-date information on lodgepole pine has contributions from 17 Forest Service authors and will greatly aid researchers and land managers in developing sound plans and future programs. —INT(762).

414. It is desirable to periodically consolidate research data which are scattered in various publications and as unpublished information, and to make this knowledge available to the land manager. Detailed status of knowledge summaries have been prepared for each of the major timber types in the central Rocky Mountains to provide information on (1) what is known about the principal tree species and (2) how this knowledge can be applied in the field. This provides the busy administrator who does not have time to read the detailed reports with a general overview and evaluation of the status of knowledge for each of the principal timber types. —RM(759).

415. Much of the existing silvicultural knowledge of subalpine forests is not being used by land managers because it is either not readily available or not in a form easily understood. The current status of knowledge on the silviculture of subalpine forests in Wyoming, Colorado, and New Mexico is described in depth for the spruce-fir and the lodgepole pine types, along with published information, unpublished research, observations, and data from practical experience. These guidelines provide the best available information on recommended timber management practices to meet a variety of uses. —RM(760).

416. Sustained yield forest management has been successfully practiced for more than a decade in the Black Hills of South Dakota but information and experience are scattered. A summary paper describes present knowledge of Black Hills ponderosa pine, including silvical characteristics, behavior, and successful silvicultural tools. This compendium will guide professional foresters and resource managers in their quest to steadily improve the yields of timber and other forest resources in this valuable resource area. —RM(763).

417. A summary publication describes the present status of knowledge on mixed conifer and aspen silviculture in the interior Southwest. Relevant literature is discussed along with observations, experience, and results of unpublished research. This status report is an excellent reference tool for prescribing silvicultural treatments and guiding management decisions in complex forest types in the Southwest. —RM(769).

418. Silvicultural practices in ponderosa pine stands of central Colorado have not always considered scenic and recreation values as major factors. Modification of conventional approaches to thinning; improvement cutting, uniform shelterwood, and group selection, plus flexible standards for growing stock levels, are now available. The practices are varied to

best fit the condition of each small unit of forest and to maintain diversity without abrupt reduction of scenic values. The practices can be (and are being) applied in the Montane Zone to maintain and improve forest values, and to make the stands better able to survive the current epidemic of mountain pine beetle. —RM(771).

419. Although ponderosa pine is the most important forest tree in the southwestern United States, research results and management prescriptions have been fragmentary. A new "state-of-knowledge" publication summarizes the most significant findings, both published and unpublished, during the past 60 years. This guide will be invaluable to resource managers for prescribing silvicultural treatments and multiple-use management. —RM(774).

420. The use of the shelterwood system to reproduce northern hardwood stands has often been avoided because of the potential damage to established regeneration when the overstory is removed. Damage to reproduction by overstory removal was found to be extensive in a study in northeastern Wisconsin, but was not significant from a silvicultural standpoint. Logging destroyed about 35 percent of the advance reproduction, but more than 45,000 stems per acre remained. Potential damage to regeneration should not be considered an obstacle by resource managers who wish to use the shelterwood system in northern hardwoods. —NC(768).

421. The economic and silviculture impacts of individual tree selection cutting practices on eastern hardwood forest stands are not fully known. In one case example in West Virginia, 12 years of selection cutting resulted in a \$76 to \$233 per acre increase in value of residual Appalachian hardwood stands, with the greatest increases occurring on the best sites. Current trends in species composition indicate that selective cutting practices will also change the species composition toward a climax stand favoring shade-tolerant, slower-growing, lower-valued tree species. These results will aid land managers involved in deciding on investments in growing timber in the Appalachian region. —NE(770).

422. There is a general misconception that sustained yield is automatic under any form of partial cutting in which trees are individually marked. A recent Pennsylvania review of what is required to make selection cutting work shows that application of various misnamed types of "selection" cutting may result in wide fluctuations in timber yield. Guidelines are presented in this review which should assist land managers in achieving a higher level of professional application of selection cutting. —NE(773).

423. Forest managers need an efficient analytical method for estimating the long-term effects of intermediate cuttings on total stand yield. A computer programming system has been developed for even-aged northern hardwoods in New England that simulates stand treatment and development, and provides thinning yields and final harvest data by species and quality classes. The simulator provides timberland owners with a much-needed management tool for quantifying the effects of alternative treatment strategies. —NE(776).

424. Improved uneven-aged management guidelines are needed to selectively manage Appalachian hardwoods. A marking procedure was recently developed that incorporates silvicultural and economic guidelines for selecting trees to cut. In practice, this procedure is applied as a flexible diameter limit using low, medium, and high rates of return on fair, good, and excellent sites. Where applicable, this silvicultural-economic marking technique is believed to be an improvement over available uneven-aged management techniques. —NE(778).

425. Although multiple-use is a valuable approach to forest management, coordinating these uses involves a number of trade-offs to reach desired goals. Theoretical multiple-use options have been developed for managing forest land in central Appalachian hardwoods, with priorities being assigned among four resources— timber, water, visual appeal, and wildlife. These options can serve as guidelines for several multiple-use decisions in conjunction with landowner objectives. —NE(779).

426. Many areas in steep mountainous terrain of West Virginia cannot be easily harvested with conventional logging equipment. A 2-month-old test of a mobile skyline yarding on the Fernow Experimental Forest using clearcutting and selection practices demonstrated that timber on steep slopes can be satisfactorily logged with favorable production and environmental results. The system is especially adapted to logging of hardwoods on previously inaccessible sites with a minimum of environmental disturbance, and has high potential for reducing the environmental impact of timber harvesting in the Appalachians. —NE(780).

427. To meet increasing demand for lumber and veneer logs, southern forest managers are being asked to produce short-rotation sawlogs. Loblolly pine sawtimber 15 inches d.b.h. was produced in 27 years on good sites in southeastern Arkansas through heavy thinning, understory control, and green pruning. At age 27, standing volume was 11.9Mb.f. per acre in intensive treatments compared to 5.3 Mb.f. in controls. But control stands had produced substantially higher merchantable cubic volume and more frequent intermediate harvests than intensively managed stands. Specific gravity was unaffected by treatment. These results illustrate the trade-off landowners must make if they wish to deliberately tailor stands for an early harvest of sawlogs. —SO(764,765).

#### Ecological relationships

428. Mountain whitethorn is one of the more abundant and troublesome shrubs on commercial forest land in California and southwestern Oregon. Origin of many mountain whitethorn brushfields evidently can be attributed to fire-induced germination of dormant seeds in the soil. Experiments show that heating soil can stimulate germination of buried seeds if followed by a cold, wet period suitable for after-ripening to overcome embryo dormancy. This information suggests that mountain whitethorn will not be a problem on new harvest cuttings if logging slash is not burned. —PNW(635).

429. New "state of knowledge" reports summarize the history, geography, geology, soils, as well as the forest resources and timber industry in southeast Alaska. Forest conditions and silvicultural practices in the western hemlock-Sitka spruce type and problems and opportunities for better timber management are discussed in detail. Addition of rather complete bibliographies make these reports valuable field and shelf reference sources for forest managers and land use planners in southeast Alaska. —PNW(636).

430. The most critical period in the life of a forest tree is during the first growing season. A controlled environment study on a central Oregon tree species showed that temperature lower than -5°C can result in considerable mortality of newly germinated grand-fir seedlings, if they are exposed longer than 10 minutes. By contrast, 6-month-old seedlings can withstand extended periods of temperatures as low as -18°C. Because much early mortality of grand fir may be due to early spring frosts, spring direct seeding should be accomplished after danger of freezing is past. —PNW(653).

431. Animal mortality in live traps has been a major problem for researchers studying small mammal populations

during winter in northern regions. A new live trap was developed in Wisconsin which provides trapped animals with proper food and water and minimizes body heat loss. Using the new trapping technique, less than 1 percent "trap mortality" was experienced in an area where continuous snow cover is present during the winter and where ambient air temperatures in the vicinity of the trap were as low as -18°C. The trap and techniques developed should materially aid and encourage small mammal research during the winter. —NC(632).

432. The Enterprise Radiation Forest was established in northern Wisconsin in 1968 to investigate the effect of massive doses of gamma radiation in natural northern forest communities. A summary publication on this unique experimental area describes the history as well as the physical and biological environment of the various communities within the forest. The 13 chapter compendium will serve as a common base for future ecological and radiological research in the northern hardwood forest type. —NC(652).

433. Past research dealing with the horizontal or elevational movement of forest tree and shrub species has been based on subjective or theoretical techniques or, occasionally, long-term remeasurement of plots. A new geometric method based on trends in tree age is now available for assessing the rate and direction of species movement. This procedure showed that yellow birch on Mt. Washington, New Hampshire, advanced in elevation annually at the rate of 1 meter, whereas black spruce retreated 1 meter. Application of the geometrical method replaces guesswork in studying elevational movements of tree-line and commercial types, and the recolonization rates of denuded areas. —NE(642).

434. Frequency and intensity of pre- and post-settlement fires have affected the composition of northeastern forests. A review summarizes what is known about effects of fire on composition of spruce-fir, northern hardwood, eastern white pine, oak, yellow-poplar, sweetgum, pitch pine, Atlantic-white-cedar, Virginia pine, and loblolly and pond pine types. This concise synthesis will significantly aid scientists and land managers in understanding consequences of wildfire and fire control programs. —NE(647).

435. Wild grapevines can be extremely damaging to central Appalachian hardwood trees in certain situations. Studies on the Fernow Experimental Forest in West Virginia indicate that grapevine sprouts cause more damage than grapevine seedlings because the sprouts grow much faster. Grapevines were found to be shade intolerant and developed more prolifically after clearcutting than after selection cutting, especially on the better hardwood sites. Nevertheless, grapevines also have considerable value in game management, so the results of the study are important in better understanding how to regulate the role of this plant species in multiple-use forestry. —NE(654).

436. Reliable methods are needed to estimate leaf biomass in forest stands to interpret the effects of silvicultural treatments. A new sampling technique which employed 15 or 30 randomly placed circular leaf traps per 0.1 hectare plot provided precise estimates of total leaf production; the results appeared to be repeatable for more than 1 year. The method was not reliable for estimating leaf production of individual species in mixed stands; however, this nondestructive sampling technique should prove useful to other scientists engaged in similar lines of research. —SE(648).

437. A major flood on the Mississippi River during spring and early summer 1973 provided valuable information on tolerance of hardwoods to flooding. Most bottomland hardwood plantations and natural stands that were 1 year old or



older were not extensively damaged by continuous flooding during the first 2 months of the growing season, but yellow-poplar plantations up to 15 years of age were completely killed. New plantings of cottonwood cuttings were virtually destroyed by 2 months of flooding, whereas only about half of newly planted seedlings that were under water about 2 weeks longer died. Flooding for 3 months killed 1-year-old planted sweetgum. This information will help landowners decide which hardwood species to plant on specific sites. —SO(638).

## Economics of Forest Management

### Methods of financial evaluation and planning

438. Combining monetary and nonmonetary values in land use planning analyses is at an early stage of development. Integrated political and economic analyses can help define goals, make clear a variety of tradeoffs, and channel planner's efforts to resolve the most critical problems. —INT(1025).

439. A computer program, MULTIPLOY, has been developed to describe the effects of forest management decisions in monetary terms. MULTIPLOY provides managers with economic analyses on losses to fire, insects, storms, or diseases; gains from genetic improvement and a number of non-timber yields. Managers are provided with a compact package for evaluating a large number of alternatives in terms of present net worth, annual equivalent income, benefit-cost ratio, and internal rate of return. This method of financial evaluation will be especially useful to forest managers making investment decisions. —SO(1026).

440. A procedure for apportioning Federal cost-share funds under the 1974 Forestry Incentives Program for silvicultural practices was developed using data on the distribution of forest area, financial returns on investments, and suitability of the respective components of the forest area to yield financial returns. Using this procedure, the South received 68 percent of the 1974 funds, the North received 31 percent, and the West 1 percent. An analysis of the sensitivity of apportionment results to data errors indicated that the overall framework of the procedure and the distribution of forest area influenced the outcome much more than reasonable fluctuations of financial returns. Though some problems remain, the apportionment system developed meets the statutory requirements with a simple procedure. The procedure and apportionment will be refined and updated as new data become available. —WO(1024,1028).

### Timber growing economics

441. In evaluating timber management alternatives, analysts must often make assumptions as to relationship of stumpage price to average tree diameter. This analysis of thinning in Douglas-fir shows that not only can alternative assumptions about price-diameter relationships produce differences in present net worth for given stands, but these differences persist over a wide range of interest rates. Choice of assumptions about price-diameter relationships should not be taken lightly. —PNW(1038).

442. Basic to analysis of any investment alternative is the ability to estimate its benefits. A series of sensitivity analyses of allowable cuts showed that, under an even-flow constraint, allowable cuts are influenced by 1) long-term growth, 2) the period that growth increases must be cumulated before they can be harvested, and 3) the amount and class distribution of the initial inventory. Analysis of the relative importance of these factors under different conditions provides useful un-

derstanding of the effect of various alternatives on allowable cut. —PNW(1034).

443. A basic determinant of the level of production of wood products is the acreage devoted to producing stumpage. The trend of a shrinking land base for timber production will probably continue. Ways to maintain or increase outputs from the remaining acres through intensive management and the potential impact of limiting timber production are discussed. —INT(1039).

444. Better guidelines for managing hardwood stands by selection cutting are needed. This method incorporates silvicultural considerations with rate of return guidelines. Rates of return were developed from growth and quality data for nine hardwood species. Trees are sorted out by species, size, vigor, and quality. Those that don't make a prescribed rate of return are marked for cutting. A valuable tool for economic management of private hardwood timber tracts is thus provided. —NE(1043).

445. Hardwoods removed from pine sites could be profitably utilized in products where quality of raw material does not affect product value or yield. Sale of these hardwoods could offset conversion costs but would also narrow the difference between future values of the pine and hardwood crops. Opportunities for conversion cover millions of acres and offer the greatest potential for boosting timber supply in the South. —SO(1030).

446. As concern for conservation of our natural resources increases, the role of forest practice legislation becomes more important. Recent laws in California, New York, Oregon, and Washington have established standards to be followed when harvesting timber or undertaking other forestry operations. Foresters can contribute their professional knowledge in the public discussion of proposed forestry legislation. —SO(1042,1052,1054).

447. Millions of acres in pine plantations require mechanized harvesting. Productivity of harvesters in shortwood, long-log, and whole-tree thinning systems was estimated from machine times and true measurements on row-thinning operations in slash pine plantations. Managers contemplating use of particular machines can benefit from study procedures for data collection, analysis, and application of results. —SO(1031).

### Multiple-use economics

448. To increase forage production in ponderosa pine stands, forest managers must understand the range implication of timber management plans. This study evaluates the feasibility of seeding forage in thinned ponderosa pine. Results show that important forage-seeding opportunities are associated with new ponderosa pine stocking guides. Informing land managers of these opportunities is an important first step toward fuller utilization of transitory range. —PNW(1050).

449. Decisionmakers often face conflicting arguments and data which are difficult to evaluate. Theoretical analysis of the incidence of costs and benefits of public policies shows that, where costs are not associated with receipt of benefits, there is a tendency for beneficiaries to lobby for alternatives that are not in the public interest. Decisionmakers can use the framework presented to evaluate the alternatives involved in the management of our forest resources. —PNW(1045).

450. One-fourth of Montana is forested. Forest resources are important to the economy and environmental quality of the State. This study describes the current status of Montana's forest resources in terms of forest zones, the structure of the forest land base, and the utilization of these resources



through recreation, grazing, mining, and harvesting. An understanding of the resources available and the alternative ways to manage them will be necessary to meet future demands on forest resources. —INT(1051).

451. To effectively manage timber and wildlife habitat, inventories should match the land capabilities with the objectives of the owners. Such inventories should also provide background for selecting and evaluating management alternatives. This suggests a two-stage inventory: 1) A moderately technical reconnaissance and 2) a more specialized diagnostic phase to chart paths for management alternatives. The first phase screens out irrelevant issues and saves time during the more expensive second phase by eliminating unnecessary measurements. This system enhances the consultant's efforts to meet landowner's objectives. —NE(1047).

452. Much information is available for planning multiple-use management of forest lands, but it needs to be integrated and expressed in terms usable by land managers. A planning framework and an allocation model which satisfies the stated objectives of multiple-use planning have been developed. Physical productivity and the interrelationships between products in the long term are primary considerations in selecting alternative management practices and the extent to which they are applied to maximize net public worth within the confines of sustained yield objectives. —RM(1053).

453. Benefit-cost analysis indicates chaparral-to-grass conversion is economically feasible on 146,200 of the 850,000 acres of chaparral in Arizona's Salt-Verde Basin. Extensive conversion could increase water runoff, increase animal carrying capacity, and reduce firefighting costs in the Basin. Though economic feasibility is not the sole determinant in land management decisions, this study helps put the potential for future chaparral conversion in perspective for land managers and others. —RM(1032,1044).

#### Impacts on forest industry and regional economics

454. Economic planners must choose planning strategies appropriate to various anticipated circumstances. This study provides the means to estimate the impact on the Douglas County, Oregon economy of changes in timber harvest, changes in appropriated funds to Forest Service and Bureau of Land Management, and changes in demand for wood products. It also provides a model for analysts to use in looking at economic impacts where raw material supply limits production. This will help planners evaluate future conditions and estimate the impact of alternative planning strategies. —PNW(1056).

455. More than 800 million slash and loblolly pines in South Carolina, Georgia, and Florida have fusiform rust stem infections. These incidence figures, applied to the entire South, indicate a stumpage loss to fusiform rust of \$28 million in 1972. This loss estimate suggests the effort that can be supported to diminish future losses. —SO(1058).

456. Structural econometric models of softwood lumber markets have derived lumber supply price elasticities of roughly 1.5. Lumber demand, on the other hand, is very inelastic in the one-year-run, less than 0.5 and maybe as low as 0.2 - 0.1. The supply price elasticity of Douglas-fir stumpage was estimated to be 0.11. A lumber demand surge is translated down to the stumpage market as a stumpage price increase which in turn shifts the lumber supply function to the left. Therefore, in an intermediate length-of-run, lumber supply may be price inelastic. While demand is the originating force behind a price surge, anything which increases the price elasticity of lumber supply, and especially of stumpage supply, will decrease the severity of a price rise precipitated by a construction boom. —WO(1083,1106).

#### Weather Modification and Weather Effects

457. Sea breeze fronts are a fire problem in coastal forests of the eastern United States. Frontal wind shifts along with increased speed can produce severe fire behavior and jeopardize fire control activities. Procedures for predicting the sea breeze fronts using an estimate of mid-morning winds, the forecasted maximum temperature, and a set of prepared tables have been developed. More effective fire control efforts through improved weather forecasting is the net result. —SE(631).

458. When weather fronts pass through an area, there is a change in forest fire danger. Results from a study evaluating frontal passages at Brunswick, Ga. indicate the 1-hour and 10-hour fuel moisture and the burning index have a definite response. This information provides needed input for safer and more efficient fire control operations. —SE(626).

459. Prediction of fog is important to many management activities. Fog is a transfer vector of disease and other airborne activities within forests and forest-related environments. Studies in Georgia have related synoptic features such as relative humidity, windspeed, and wind direction to fog development. Additional studies concluded that accuracy of atmospheric sampling is a major factor in fog prediction. Sophisticated statistical procedures have also been developed to better evaluate research efforts. Results of these studies will enhance our ability to predict fog. —SE(621,624,626,629).

460. In order to more fully develop, model, and apply information on fire behavior, smoke dispersal, pollen dispersal, and other wind-related forest phenomena, it is necessary to determine the distribution of velocity through the forest canopy and its resultant effects. Research results indicate wind distribution in the canopy can be modeled. There is an apparent independence of wind and temperature which tends to support use of stand averages in energy balance work. A computer diagnostic model has also been developed to evaluate smoke plume configurations. The wind modeling research will materially assist our commitment to manage forest lands with minimum negative impact on air quality. —RM(617,618,623).

461. Scaling parameters are needed components for the development of bioclimatic models. Vertical air temperature profiles measured in a Wyoming pine stand indicate that maximum temperatures of composite profiles are found at the level of maximum foliage concentration and at the floor of the stand. In support of this modeling work, procedures have been developed to analyze the sensitivity of model parameters. The sensitivity analysis is important in the model verification, interpretation, and analysis. Modeling work is an integral part of our efforts to continually improve and sustain quality forest management nationwide. —RM(619,622).

462. Diagnosis and prediction of winds in mountainous areas are needed for determination of such data as fire spread rates and potential of advection and movement of air pollution in forested areas. A new model predicts surface windspeeds and directions at remote locations on a square grid with grid points approximately 208 feet apart. Wind prediction at these grid points can be made for up to 24 hours at remote locations where few or no observations are available. The model furnishes winds and wind fields to predict spread rates of wildfire, penetration of air pollution into forested areas, or smoke trajectory from prescribed burns. —PSW(628).

463. The Forest Service will have increasing need for meteorological information in the form of observational data

and diagnostic and prognostic numerical simulations to apply to a wide range of forestry problems including fire, environmental planning, hydrology, disease and insect studies, and forest management. Results of the study show that the Forest Service, as well as other agencies, must rely on the National Weather Service for synoptic scale information, join with other regional agencies to combine mesoscale information generation, and should expect to fill its own needs for topocscale information and specialized user requirements. Numerical modeling based on scale stratification is shown to be a reasonable approach toward satisfying Forest Service meteorological needs on a limited budget. —PSW(630).

464. Managers engaged in fire danger rating and fire protection planning have a method of obtaining reasonably complete weather observations from remote areas in their districts or rating zones without having to send someone to get the data or station someone there to make the measurements. Automation of the weather observations is the answer. One effort involves the development of an inexpensive, reliable, and semi-automatic fire weather station. A second effort involves a contract with Honeywell to modify the U.S. Air Force droppable weather station to fire weather needs. The third effort is a sophisticated automatic meteorological research telemetry network. The inexpensive weather stations being developed in California are prototypes for a nationwide network of fire weather stations and the Honeywell stations are prototypes for weather stations that can be deployed around ongoing forest fires. —PSW(625).

465. Research meteorologists need a statistical procedure to analyze periodicity of temperature and wind functions over southern California. A harmonic analysis algorithm is programmed for use on the Hewlett Packard 9820-A programmable calculator. The program is versatile in its acceptance of various meteorological variables. Values are statistically tested for their relationship to original data. The harmonic analysis program provides researchers and others a quick and easy method to analyze, describe, and model periodic phenomena such as hourly values of temperature, relative humidity, and fuel moisture throughout the day. —PSW(620).

466. Lightning modification is considered to be a viable means of reducing the severity of the lightning fire load. Results show silver-iodide and metallic chaff seeding of thunderstorms are two promising means of producing lightning modification. Research is still needed to clearly identify the full potential of this new technology. —INT(606).

467. USDA Forest Service interest in modifying storms stems from the continuous destruction of forest resources by wildfires ignited by lightning. Two lightning modification experiments were conducted in Western Montana in the 1960's. A summary of this work as well as results of weather modification research undertaken at the Northern Forest Fire Laboratory are presented to aid in future research. —INT(601).

468. Irrigation in central Washington State from 1950 to 1971 produced little climatic change either inside or outside the irrigated area. Trends in summer air temperature and rainfall during July and August and open pan evaporation were examined at stations inside and outside the Columbia Basin Project. Pan evaporation gave the most sensitive measurement of the small integrated effect of irrigation on the environment of the area. The study suggests no secondary precipitation benefits accrue to areas receiving irrigation treatments under conditions like those prevailing in central Washington State. —PNW(73).

469. Residues resulting from forest harvest or natural events influence regenerating plants by altering the microclimate. Basic physical processes underlie the development of local microclimates. Opportunities to affect these processes by residue generation and treatment were examined with respect to a simplified energy balance model and by demonstrating effects of residue types on surface heating and cooling. Change in exposure and surface physical properties due to residue treatment produces important modifications of the energy balance. —PNW(70).

## Reclamation of Mined Lands

470. Little quantitative information is available concerning revegetation of mine spoils in Western United States. First-year results of revegetation research at the Decker coal mine in Montana indicated that several combinations of grass seed mixtures, fertilizers, mulch, irrigation, and top-dressing produced acceptable grass stands. Top-dressing of mine overburden appears to be a desirable practice. This research project will be useful to those planning reclamation of mined land. —INT(30).

471. Guidelines have been developed for predicting the rehabilitation potential of surface-mined lands in the Northern Great Plains. The guidelines are based on: (1) Amount and distribution of precipitation, (2) suitability and availability of plant materials, and (3) soil productivity and stability. The potential for rehabilitation is greatest in such areas as west-central North Dakota, and lowest in southeastern Montana and western North Dakota. This information will provide guidance in decisions on how to conduct surface mining operations, along with a better understanding of the expected effectiveness and cost of rehabilitation. —INT(33).

472. Massive structural failure and surface erosion can take place in improperly designed mine spoil dumps and associated road fills. Spoil dumps placed on slopes of 3 to 1 or less should not be subject to failure even under saturated conditions. Streams approaching 0.8 cfs in mine dump soils will cause significant erosion. These results will be useful in planning mining and reclamation operations so as to minimize sedimentation of streams and other environmental damage. —INT(31).

473. Direct seeding of pine is an appealing method of reforesting spoil banks, but results of most field trials have not been encouraging. To pinpoint the trouble, greenhouse studies were recently made of seven pine species sown on 12 Kentucky spoils. It was concluded that the best opportunities for success are with longleaf and loblolly pine sown on sites with coarse-textured spoil with pH between 4.1 and 5.0. These preliminary results will assist in development of reliable procedures for direct seeding of plants on surface-mined lands. —NE(34).

474. Competition by herbaceous plants has often been a problem in tree establishment. In a study of plant competition on coal mine spoils in eastern Kentucky, herbaceous vegetation did not significantly affect tree survival, but tree growth was suppressed by grass cover. On the other hand, tree growth was enhanced in cover dominated by legumes. Chances for establishing trees on mine spoils seeded with herbaceous species can be increased by encouraging rapid establishment of legumes and avoiding strongly competitive grasses. —NE(41).

475. Reclamation of refuse from underground bituminous mines is a major problem in Pennsylvania. Chemical characteristics of the spoil refuse appear to be responsible for limiting plant growth. On most areas, lime, fertilizer, and mulch



were essential to the establishment of weeping lovegrass, K-13 tall fescue, Korean lespedeza, and red pine. A vegetative cover on these spoils enhances their esthetic qualities and reduces dust, erosion, and water pollution. —NE(28).

476. Herbaceous vegetation is usually planted on mine spoils only in the spring. However, this has not always provided cover in time to prevent erosion. On mine spoils in eastern Kentucky, procedures have been developed that will provide vegetative cover within 45 to 60 days after seeding from March 1 to October 15. For summer seedings, warm season, annual species were especially useful for providing quick cover. Seedbed preparation was found to be essential for successful seedling establishment. —NE(42).

477. Use of fly ash from power plants for reclamation of surface mining offers an attractive outlet for large tonnages of this waste material. A study describes changes that occurred in spoil in West Virginia following the application of 150 tons of fly ash per acre. The treatment neutralized acidity, added plant-available phosphorus, lowered spoil density, and increased subsurface moisture. The results may encourage greater use of this waste material for the reclamation of drastically disturbed areas. —NE(38).

478. Planting success with containerized tree seedlings has encouraged use of this system on coal mine spoils in Pennsylvania. Plastic tubelings were found to be subject to serious frost-heaving, however. Of the containers tested, peat pots and Jiffy-7's were most resistant to frost-heaving. Compared with bare-root seedlings, seeded red pines in peat pots and Jiffy-7 containers performed well. —NE(29).

479. There is much variation in growth rate of Virginia pine on mine spoils due to site characteristics and genetic factors. The importance of these factors was studied on acid mine spoils in southeastern Kentucky, using seed from Kentucky and Tennessee. Seed from eastern Tennessee produced slightly taller trees. A genetic gain is possible using a process of selection, and this may be increased on sites where careful mining techniques and cultural practices have resulted in relatively uniform spoil conditions. —NE(39).

480. This field manual provides information and guidelines for revegetating surface mined lands in the eastern Kentucky coal fields. Items specifically discussed include: predicting problem spoils, problem coal seams, physical and chemical properties of spoil that affect vegetation, spoil sampling and testing, vegetation selection and establishment, site preparation and seeding methods, fertilizer selection and application, mulch

selection and application, and treating acid spoils. This manual will assist those responsible for proper revegetation of mine spoils, such as mine operators and state reclamation inspectors, to do the revegetation job more easily and successfully. —NE(40).

481. Control of stream sedimentation is an important goal of surface mine reclamation. Effectiveness of mining practices and control structures in reducing sediment was studied in West Virginia. Impoundment structures removed 60 percent of the suspended sediment resulting from low to moderate intensity storms but were not always effective during severe storms. Improvements in structure design and other reclamation techniques should further reduce sediment in streams and rivers. —NE(43).

482. Little quantitative information has been available about the effects of various mining practices on erosion and sedimentation. Recent measurements of sediment accumulation in debris basins below surface-mined lands in eastern Kentucky show highest sediment yield during the first 6 months after mining. Erosion and subsequent sediment yield appears to have a half-life of 6 months. Results of this study suggest that if the amount of sediment produced during the first 6 months is known, it may be possible to predict the yield for any 6 month period or the total yield. —NE(27).

483. Successful stabilization of surface-mine spoils and other drastically disturbed areas depends on the establishment of a grass and legume cover. Mulches and soil stabilizers may be used on problem sites to help establish vegetation and reduce erosion. Two cooperative demonstrations in West Virginia compared vegetation establishment and erosion loss following 30 treatments with 6 mulches and 12 soil stabilizers. There is no evidence that these materials are necessary for vegetation establishment; they are used primarily to control erosion. —NE(37).

484. Over the years, spoil slides have disturbed thousands of acres in Appalachia. These slides result in an unnecessary loss of natural resources, and their raw surfaces intensify the quantity and persistence of sediment and chemical pollution of streams that drain mined watersheds. An investigation of the causes of slides in contour strip coal-mines in eastern Kentucky revealed that the incidence of slides is not related to steepness of terrain. Storage of spoil on excavated benches reduced the area disturbed by slides 42 percent. Instability of spoil dump outcrops is still excessive, but can be reduced as knowledge of physical and mechanical properties of spoils is developed and applied. —NE(44).



# IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES

## Intensive Culture Methods

### Site evaluation and soil improvement

485. It is difficult to obtain accurate estimates of cubic foot volumes in scaled logs. A review of current scaling practices in the Pacific Northwest shows dropping fractional diameter measurements results in lower recorded diameters than those obtained by measuring to the nearest one-tenth inch. This biases cubic volume estimates by 10 percent or more in small diameter logs. Fractions should be retained or recorded diameters should be fully adjusted to get accurate cubic measurements using sawlog scaling procedures. —PNW(867).

486. What cultural measures should managers use in coastal Douglas-fir stands? A review indicates a 30 percent gain in yield can be obtained from a combination of precommercial and commercial thinnings. Further substantial gains can be expected from fertilization and genetic improvement. Recent information brings these and other considerations into proper perspective in evaluating opportunity and expected benefits from intensive management of Douglas-fir stands. —PNW(663).

487. Even though there are extensive commercial forests in southwest Oregon, little information on how to increase tree growth is available. In a 30-year-old, Site IV stand of Douglas-fir, fertilization increased average 4-year basal area growth of dominant trees by 57 percent over control growth on a clay loam soil. Thinning increased growth by 53 percent. When combined with thinning, fertilizing increased growth by 94 percent on the clay loam soil and 132 percent on a nearby sandy loam soil. Both fertilization and thinning can be used to increase tree growth on dry Douglas-fir sites. —PNW(675).

488. Prescriptions must be improved if fertilizer is to become a practical silvicultural tool. Nitrogen fertilizers increased basal area growth of 75-year-old, codominant Douglas-fir trees on a highly productive soil in western Washington. Although the six treatments tested increased average 5-year basal area growth by 17 to 53 percent over control growth, only ammonium nitrate at 300 pounds of N per acre increased growth significantly over no treatment. Increased growth from fertilized mature stands provides high value wood which can be quickly harvested. —PNW(674).

489. Lodgepole pine often occupies frost pocket areas in central Oregon to the exclusion of ponderosa pine. Previously, it has been shown that lodgepole pine is more tolerant to low temperatures during the seedling emergence period than is ponderosa pine. In this more recent investigation, lodgepole pine floral structures also were found to be more frost resistant than ponderosa pine. A temperature of  $-2.2^{\circ}\text{C}$  killed 88 percent of ponderosa pine flowers but only 2.6 percent of lodgepole pine flowers. This information helps explain why lodgepole pine occupies flat depressions as pure stands. —PNW(681).

490. Sound guidelines are needed to develop operational fertilization programs for intensive timber culture. A recent

evaluation of the important methods of diagnosing forest need for—and response to—nutrient change proposes a six-stage program for operational fertilization. The program provides an efficient and effective guide for assessing the fertility status of forest sites, the nutrient deficiencies that exist, and the quantities of nutrients needed for optimal growth. The program provides forest land managers with a guideline for fertilization decisions. —PSW(676).

491. Red pine productivity cannot be adequately estimated from soil properties, and growth response to nutrient levels is unknown. A study of 50 red pine stands in north-central Minnesota provided an estimate of site index for two distinct groups of soils: those with a well-developed B horizon or textural banding below the solum (Group I), and those without textural differentiation (Group II). Site index estimates are based on nutrients and cation exchange capacity in the surface 25 cm of the mineral soil. Nitrogen or phosphorus may be limiting tree growth in 1/3 of the stands. The most likely fertilizer responses should come from phosphorus in Group I soils and nitrogen in Group II soils. Improved estimates of productivity for red pine forests can now be made from soils information before planting. —NC(655).

492. Variations in forest soils cause difficulty in adequately and efficiently sampling soil chemical and physical properties for use in red pine and aspen management. In Minnesota, red pine or aspen stands require only two samples to estimate pH, bulk density, or sand to  $\pm 10$  percent with 95 percent confidence. Estimates of nutrients, available water, or silt plus clay, on the other hand, require 25 to 60 samples. Most properties of the forest floor require 30 to 50 samples in red pine stands, but only about half as many in aspen stands. These results provide managers with efficient means of sampling soils for specific physical or chemical soil properties. —NC(657).

493. Large scale commercial planting of Caribbean pine is now underway in Peninsular Malaysia, but is hampered by the lack of specific information on growth and yield of this species on the large variety of soils found in Malaysia. A recent cooperative research venture showed that Caribbean pine makes very rapid height growth on soils developed from granite—10-year-old trees averaged about 65 feet tall. Poorer height growth occurred on soils developed from shale and sandstone, but growth was often improved by phosphorus fertilizer. Growth of Caribbean pine in Malaysia is equal to or better than in most other tropical countries. These results will be useful to forest land managers in Malaysia in identifying the most productive sites for Caribbean pine plantations. —NC(661).

494. Site index curves constructed from regional data are not suitable for determining site index from height-age data in Missouri, particularly at ages less than 50. New site index tables, factors for converting site index of one oak species to that of another oak species, and confidence intervals based on number trees measured for Missouri conditions are now available. This information will be especially useful to land managers in accurately determining site index for oaks in one major section of the central hardwood region. —NC(672).

495. Nutrient concentrations in forest tree leaves are used to evaluate possible response to fertilization, but little is known about the sensitivity of leaf parts to changes in external nutrient supply. A study in West Virginia showed that yellow-poplar leaf blades are more responsive to changes in external nutrient supply than petioles or whole leaves. Blades provided a more sensitive and accurate measure of nutrient concentration than petioles or whole leaves. These results clearly show that for comparable and consistent nutrient estimates, a uniform procedure should be developed for collecting and analyzing yellow-poplar foliar nutrients. —NE(658).

496. Information on fertilizer application to stimulate early height growth of paper birch and yellow birch regeneration after clearcutting northern hardwoods in New England is scarce. A surface application 4547 Kg/ha dolomitic limestone and 1165 Kg/ha of 15-10-10 NPK fertilizer after clearcutting resulted in a threefold increase in seedling biomass in 4 years. Although large numbers of birch seedlings regenerated in the fertilized stand, pin cherry and shrubs dominated the stand in both numbers of seedlings and above-ground biomass. These results suggest that lime and fertilizer treatments immediately after clearcutting and site scarification may not be favorable for adequate stocking and development of birch regeneration unless pin cherry is controlled. —NE(678).

497. The effect of lime and fertilizers on root development must be known if managers are to effectively improve forest tree growth. In a 90-year-old birch-beech-maple stand in New Hampshire, fine root biomass in untreated plots averaged 1246 g/m<sup>2</sup>; after addition of lime, 1229 g/m<sup>2</sup>; and after addition of lime and fertilizer, 2711 g/m<sup>2</sup>, or more than a twofold increase over no treatment. Biomass increase from soil amendments extended through the soil horizons to all but the C layer. Concentrations and contents of various nutrients increased significantly in the fine roots. These positive consequences of fertilization should lead to a gradual improvement in fertility of the deeper soil horizons and to increased windfirmness, in addition to the immediate benefits to growth and vigor of the forest stand. —NE(677).

498. Currently available apparatus for obtaining small samples of soil air are unreliable or difficult to use in the field. A simple device using porous plastic reservoirs was developed and used in a loblolly pine plantation. Samples obtained from the reservoirs showed CO<sub>2</sub> content of the soil atmosphere followed a gradient from about 0.03 percent at the surface to 1.2 percent at a depth of 60 cm. The porous reservoirs, combined with atmosphere analysis by gas chromatography, provide a procedure whereby soil aeration and other gas-related processes may now be examined simply and quickly. —SE(666).

499. Intensive culture and artificial regeneration change the natural ecosystems of the southeastern coastal flatwoods to promote pine growth. Disking and bedding forest sites in north Florida nearly eliminated saw-palmetto while panicum grasses, bluestems, blueberry, and blackberry became the dominant early successional vegetation. Future ecological research should study the role of saw-palmetto in flatwoods ecosystems so predictions can be made on the effect of widescale destruction of this shrub as a result of intensive forest management. —SE(680).

500. Site index curves are widely used in estimating growth and yield, but some existing site curves often contain weaknesses which are inherent in their methods of preparation. New site index curves have been developed from stem analysis data for loblolly pine in the Atlantic Coastal Plain of the Carolinas and Virginia. These new curves give unbiased estimates of site index that are consistently better than those

generated by existing curves. This information should provide landowners with better estimates of the growth potential of their forest lands. —SE(682).

501. More information is needed on the fate of applied nutrients if fertilizers are to be used efficiently and effectively in southern pine forests. In a Mississippi study, young loblolly pine plantations that were fertilized with 112 and 224 kg N/ha as ammonium nitrate produced 25 percent more total above-ground biomass and accumulated 30 percent more nitrogen in 2 years than unfertilized plantations. The pines utilized more of the nitrogen if one-half the fertilizer was applied in April and one-half in August than if all was applied in April, and more if competing vegetation was sparse than if it was abundant. This information will be valuable in developing fertilizer prescriptions for southern pine forests. —SO(659,883).

502. The increasing demand for wood products, coupled with a decrease in available forest land, makes fertilization a potentially useful silvicultural tool for boosting hardwood growth. Nitrogen (N) and nitrogen-phosphorus (P)-potassium (K) additions increased diameter and height growth of sweetgum, water oak, and willow oak on clayey Mississippi River floodplain soils by 40 to 60 percent. A single application of 1000 pounds of NPK per acre to eroded soils of the silty uplands increased yellow-poplar heights by 41 percent over a 5-year period. Application of 150 pounds of N per acre increased volume growth up to 200 percent in cottonwood stands established on nutrient-deficient old fields in the Mississippi River floodplain. These results provide fertilization prescriptions which will help the Nation meet its demand for hardwood. —SO(660).

503. Accurate information is lacking on relationships between site quality, total dry matter production, and plant nutrient content. In 19-year-old unthinned loblolly pine plantations in southeastern Arkansas, the ranking of four sites in descending order of total dry matter in boles, branches, and foliage and in quantities of P, K, and Na in boles was: Coastal Plain poorly drained, Coastal Plain well drained, loess well drained, loess poorly drained. Only drainage influenced quantities of N and Ca in boles: N was higher and Ca was lower on poorly-drained than on well-drained soils. Bark contained 44 to 50 percent of the nutrients in boles. Landowners can now estimate quantities of nutrients removed by timber harvesting on these important forest sites. —SO(668).

504. Dense stands of native grasses reduce survival and retard growth of direct-seeded southern pines on open cutover sites. Mechanical preparation of such sites before sowing about doubled stocking of loblolly and slash pine at age 10 on a silt loam soil in Louisiana. Loblolly pines on flat- and mound-disked strips were 2 to 4 feet taller than those sown in an undisturbed rough. Slash pine growth was not improved. This information will aid landowners in deciding which sites they should prepare mechanically before direct seeding. —SO(669).

505. Growth of slash pine on low sites of the southern Coastal Plain is often restricted by excessive soil moisture. In a Louisiana study, response of planted slash pine to bedding depended upon the increase in average depth to free water during January and February—the period when soil is ordinarily saturated. For each centimeter increase in average depth to water, to a depth of 45 centimeters, stemwood yield at age 8 rose 300 kg/ha and total biomass rose 659 kg/ha. These results will permit landowners to assess the value of bedding prior to treatment. —SO(671).

506. Although bedding and fertilization are popular site treatments in the Gulf Coastal Plains, results are erratic. On



sites where water stands on or near the surface for 8 to 10 months of the year in northwest Florida, trees growing on high beds (10 inches above the normal ground line) were 5 feet taller at age 8 than those on flat-disked ground. On dry and intermediate sites, bedding did not improve tree growth over diskings. Top dressing of the wetter sites with 1000 pounds per acre of phosphorus as triple superphosphate at age 2 years improved growth an additional 2 to 5 feet. Forest landowners can now estimate early returns from bedding specific sites. —SO(670).

507. Nutritional balance is generally considered important in the development of seedlings. New information has been developed through a PL-480 grant which relates the effects of potassium, magnesium, and calcium to growth and development of Norway spruce seedlings. Results show that seedlings are very tolerant of media unbalanced in their content of metallic ions, and the concentration of mineral elements in spruce seedlings was highest when its supply was at the highest level and the supply of other elements was limited. These results will be valuable in developing and interpreting fertilization regimes for nurseries in the United States. —WO-TMR(665).

508. Few non-leguminous vascular plants form root nodules, some of which are associated with nitrogen fixing bacteria, an extremely important attribute for maintaining and increasing site fertility. A study of root nodules has identified two non-leguminous types, of which one (alder-type) is associated with nitrogen fixation while the other (podocarp-type) does not appear to be important in this role. However, the podocarp-type nodule enhances the ability of plants to absorb phosphorus which may be valuable for colonizing wastelands where phosphorus deficiency is a limiting factor. —WO-TMR(667,679).

#### Artificial regeneration

509. Millions of seedlings are now grown in containers, but very limited evaluations have been made of their field performance. A method has now been described for making uniform field comparisons of containerized and bareroot nursery stock and field comparisons are being installed on National Forests in Oregon and Washington. If such studies are made in many areas, enough data can be cooperatively accumulated from which to develop sound guidelines for using both containerized and bareroot seedlings. —PNW(824).

510. The lack of easily-measured maturity indices for cones and seeds of white fir and red fir has often resulted in collections of immature seeds. Research in northern California has shown that white fir cones can be collected when they average about 0.96 specific gravity—usually 3 1/2 weeks before seedfall begins. Red fir cones should not be picked until their specific gravity averages about 0.75, very close to time of seedfall. These guidelines should improve seed quality in collections of these species, thus benefiting nursery and regeneration programs. —PSW(823).

511. Separating tiny seeds from chaff is difficult with small lots of many species. A simple method devised in California shows that small seed lots can be cleaned easily and quickly by decanting the seeds repeatedly from plastic to glass containers. After the plastic container is charged with static electricity by wiping it with a cloth, chaff and empty seeds will adhere to the sides of the container. This method provides a quick, cheap, and effective way for seed handlers to clean small seeds. —PSW(838).

512. Artificial regeneration in Hawaii is difficult and costly with bare-root or bagged seedlings because of the rugged

topography and rocky soils. Recent tests with containerized planting stock have shown that polystyrene bullet containers, popular elsewhere, are unsatisfactory for conditions in Hawaii. Planting the bullets was very difficult in typical forest soils. These results will shift efforts to more promising techniques. —PSW(846).

513. More efficient and effective reforestation systems are needed for Hawaii. A Styroblock container system developed in British Columbia appears to meet these criteria for the species and soils of the Islands. Three months after outplanting seedlings of four valuable species, survival exceeded 95 percent for all, and more than 90 percent of the seedlings were growing vigorously. Planting holes were easily prepared with a dibble on a wide range of soils. These results indicate that the Styroblock system can improve Hawaii's reforestation program. —PSW(847).

514. Tree species adapted to infertile, eroded slopes and ridges are needed for watershed protection in Hawaii. At 3000 feet elevation on the Island of Molokai, five pine species from central Mexico have grown vigorously to an average height of 9 to 11 feet in 5 years. These species and four others planted at 6400 feet on the Island of Maui are also growing well. This satisfactory performance gives the Hawaii land manager greater flexibility in species selection for reforestation projects on medium and high elevation sites. —PSW(848).

515. Storage temperatures are an important factor in maintaining healthy planting stock between nursery removal and planting. Comparison of root-mass temperatures between tree packages in culvert or pit snow caches in the mountains of Idaho and Montana and in refrigerated coolers indicated that the snow cache provides better temperature control. Snow storage is cheaper and also appears to provide superior conditions for seedling storage. Guidelines are now available on proper location and installation of snow caches which will enable foresters to successfully store nursery stock on or near the planting site until it is needed for planting. —INT(809,832).

516. Direct seeding has been an effective regeneration method in many regions, but in the Southwest, young seedlings are frequently frost-heaved. Tests conducted under closely controlled conditions (in a chest set in a deep freeze) indicated that frost heaving was directly related to soil bulk density. Several chemicals, such as ferric chloride, calcium chloride, and calcium sulfate, applied at lower non-phytotoxic rates reduced frost heaving in both laboratory and field experiments. Plowing to lower the soil bulk density may be a practical method of reducing frost heaving. —RM(813,814).

517. Spot seeding seems attractive as a possible means of reforesting large areas of mixed conifer forest in the Southwest denuded by fires, insects, and clearcutting. Spots were seeded on three mixed conifer clearcuttings on favorable sites in Arizona, using southwestern white pine and blue spruce, which are adapted to full exposure. After three summers, the seeding was a total failure. Rodents and frost heaving were the major factors. Spot seeding is not promising for reforesting mixed conifer lands in the Southwest. —RM(815).

518. Mulching was tested as a supplementary measure to increase ponderosa pine seedling survival on difficult planting sites in Arizona. Survival of 3-0 spring planted seedlings mulched with clear and black polyethylene, volcanic cinders, woodchips, and dead grass sod was generally unacceptable. Results indicate that mulching is not a satisfactory substitute for complete site preparation careful planting of vigorous stock, and early protection from grazing, fire and competing vegetation. The value of mulches as an aid to survival and growth of ponderosa pine in the Southwest remains uncertain. —RM(827).



519. Mortality of Engelmann spruce planted in high elevation openings is often severe. Research in the subalpine forest zone of Colorado found that intense light at high elevations inhibits photosynthesis of young seedlings and may cause death. When Engelmann spruce seedlings are planted at high elevations, care should be taken to place them only in acceptable microsite such as the north and east side of down logs, stumps, or slash, where shadow offers protection from direct sunlight. —RM(828).

520. A newly developed greenhouse system for growing containerized tree seedlings avoids many problems of outdoor nurseries. In 1 year, greenhouse grown seedlings in North Dakota are equivalent in size to 3-to-4-year-old nursery stock grown outdoors on the Great Plains. This new greenhouse-container nursery will provide better seedlings faster, and over more of the year than the bareroot nursery. This technology will aid the reforestation effort throughout the United States. —RM(839).

521. Geneticists frequently need to root ponderosa pine cuttings in order to obtain plants with the same shoot and root genetic makeup. Recent research has shown that grafting of ponderosa pine cuttings on exposed roots from the tree the cuttings were taken from is much more successful than direct rooting. This technique will be a useful aid to the genetic improvements of ponderosa pine. —RM(840).

522. Widespread interest has developed throughout the United States and Canada in perfecting reliable, economical systems for producing containerized tree seedlings for reforestation. Literature on raising containerized stock in greenhouses is widely scattered. The current status of knowledge on all aspects of containerized planting in North America was reviewed at a 3-day symposium in Denver, Colorado, in August 1974. Of the 90 papers given at the symposium, 33 were authored or coauthored by U.S. Forest Service scientists, specialists, and administrators. The proceedings will be a valuable reference to administrators, educators, and scientists. —PNW(841).

523. Irregularity of good seed crops in many forest tree species requires storage of seed stocks for several years to insure a reliable supply of seed. Recent results in Wisconsin have demonstrated that, with proper storage, viability can be satisfactorily maintained in yellow birch and paper birch seed lots for at least 8 years. The seeds should be kept in closed containers at temperatures of 36° to 40°F. This information will aid nurserymen and others who need to store birch seeds over a period of several years. —NC(807).

524. Heavy mortality of coniferous planting stock is a continuing problem in the Lake States. A systematic evaluation of tree size, packing methods, distribution, location, and planting showed that careless planting is the most important cause of failures of newly planted red pine in northern Minnesota. Distribution procedures and high root/shoot ratios are also problems. Guidelines are provided which could result in much greater returns on planting investments. —NC(808).

525. Large yellow-poplar seedlings are known to survive and grow better than smaller ones in the years immediately after outplanting. Sixteen years after outplanting in southeastern Ohio, yellow-poplar seedlings with original top length greater than 15 inches continue to outgrow those that were less than 10 inches long. Survival of the taller seedlings is also better, and 48 percent have a straight lower bole, in contrast to 26 percent of the short seedlings. Silviculturists can expect to reduce rotations by 3 years when tall rather than short trees are planted. —NC(811).

526. Little is known about the effect of root media on the development of container-grown red pine seedlings. After 16 weeks, seedlings grown in a 1:1 mixture of peat and vermiculite were larger than those grown on eight other mixtures containing two or three of the following materials: peat, vermiculite, arcillite, sand, and loam. The peat-vermiculite mix also possessed the highest cation exchange capacity and retained moisture longest. This information will result in improved containerized red pine planting stock. —NC(825).

527. Mechanical seed counters are commonly used to obtain uniform subsamples of a specific number. A study in Wisconsin, however, has indicated that in jack pine and white spruce seedlots of varying seed size and weight, the use of vibratory electronic counters does not consistently produce representative subsamples. The last few subsamples from a seedlot contained up to 90 percent more empty seeds and weighed up to 70 percent less than the population mean. Awareness of this bias will enable seed handlers to take steps to ensure that samples are representative of the seed population. —NC(829).

528. Survival of planted black walnut seedlings has usually been good, but early growth is typically poor, especially during the planting years. It was recently found that neither planting method nor planting stock treatment had any appreciable effect on survival and growth. The best planting method was the one most convenient for the planter as long as it was compatible with the type of planting stock. Tree planters therefore can use any of several standard planting methods to establish walnut plantations. —NC(849).

529. Unseasonable cold periods may result in major losses of hardwood seedlings in young tree nurseries and in newly established plantations. Many black walnut seedlings growing in a southern Indiana nursery were topkilled by a November freeze. Seedlings from Kentucky, Tennessee, and Alabama were more seriously damaged than those from Michigan. Seedlings fertilized with ammonium-type fertilizers were less severely affected than unfertilized seedlings or those treated with sodium nitrate. These results are now being used by nurserymen and tree planters throughout much of the Midwest to minimize the risk of cold damage in growing walnut seedlings and in establishing new plantations. —NC(850).

530. Simple, efficient, and effective methods of direct seeding are urgently needed by forest managers in the Northeast to establish white pines on areas heavily occupied by non-commercial species. A furrow seeder was developed from available agricultural equipment that successfully direct seeded white pines behind a fire line plow at a sustained rate of 1 to 4 acres per hour. Costs of the operation were about one-third those of planting nursery grown stock on similar sites. The use of this regeneration technique can help to prevent visual degradation and/or injury to fragile ecosystems. —NE(812).

531. Sugar maple produces good seed crops at irregular intervals which vary from 2 to 7 years. To insure the availability of adequate seed supplies during poor crop years, we needed to know the requirements for long-term storage. It has now been found that sugar maple seeds store best at 10 percent moisture content and at -10°C. This information will help nurserymen better plan their annual seedling production programs and also assist seed dealers in maintaining continuing seed inventories. —NE(851).

532. Intensive culture of fast-growing hardwood species on short rotations may be necessary if the United States is to meet future wood fiber commitments. Scientists from Georgia have summarized intensive cultural practices for the management of commercial hardwood plantations in the South. Using present technology of weed and water control plus fertiliza-

tion, growth of sycamore and cottonwood averages between 3 and 4 cords per acre per year. Results show that practical methods are available for growing hardwoods under several management systems and for different product goals. —SE(801).

533. Authorities disagree on how deep longleaf pine seedlings should be planted. In a Florida study, longleaf pine seedlings (1-0 stock) planted with root-collars at the ground line, were taller, healthier, and more abundant after 5 years than those where the bud was covered with 1 to 3 inches of soil. Thus, deep planting offers no advantage when regenerating longleaf pine on sandhills sites. —SE(804).

534. Sycamore can be established by vertical planting of unrooted cuttings, but cheaper methods of regeneration would be desirable. A recent test of sprouting and survival of horizontally planted sycamore cuttings suggests that large-scale plantings are feasible by this method. The pattern of root development was influenced by number and position of sprouts, by depth of planting, and by cultivation. This technique has the potential to provide a cheaper, mechanized way of establishing sycamore plantations. —SE(752).

535. Reliable methods are needed for vegetatively propagating genetically superior hardwoods for planting in seed orchards and for use in ecological and physiological investigations. Physiologically juvenile 1- or 2-year-old cuttings from individual trees representing ten genera of important southern hardwoods have been successfully rooted using relatively simple propagation techniques. Stump or root-collar sprouts are the preferred source of physiologically juvenile cuttings, but forced epicormic branches from the lower 4 to 6 meters of the bole of mature hardwoods also give good results. The procedure greatly simplifies the task of mass producing genetically uniform planting material. —SE(817).

536. Reforestation programs are normally based on proper selection of seed source, but for some species, elevation of the source has often not been considered. A recent study in North Carolina has shown that northern red oak phenology is highly correlated with elevation of acorn sources. When outplanted at common sites, seedlings from high elevations broke dormancy later than seedlings from low elevations. This information can be used in planting programs to obtain maximum seedling growth and avoid frost damage to low elevation sources. —SE(820).

537. The physiological bases for the competitive advantage of one tree over a neighbor of the same species are poorly understood. Research in Georgia with propagules of fast- and slow-growing clones of yellow-poplar emphasized the important role of early root development in future competition between trees. The shoot/root ratio of these clones also appeared to be under genetic control. This information will help explain certain aspects of competition, and it illustrates the practical importance of clonal mixtures in artificial regeneration. —SE(837).

538. Loblolly pine seeds that have been conditioned for prompt, complete germination by moist chilling must sometimes be stored for a year or more before they are sown. Fully imbibed seeds were stored satisfactorily for 1 year at temperatures between 1° and 15°C. Lower or higher storage temperatures reduce viability. An even safer procedure was to dry the imbibed seeds to 10 percent moisture or less and store them at near freezing temperature. These results will give seed dealers, nurserymen, and landowners additional options for handling stratified seeds. —SO(799).

539. Tap roots of containerized southern pine seedlings frequently grow through the bottom of the container before

the trees are ready to outplant. When containerized loblolly pine and longleaf pine seedlings were grown on and off a copper screen base for 1, 2, 3, and 4 months, copper effectively prevented growth of the roots from the tubes and resulted in increased survival at all seedling ages for loblolly pine and with 4-month-old seedlings for longleaf pine. Top growth was not affected. These results clarify the effects of an important variable involved in producing containerized planting stock. —SO(798).

540. Three basic questions to be resolved in developing a reliable containerized planting system for southern pines are tube size, age of planting stock, and planting environments. A Louisiana study in which longleaf, loblolly, and slash pines were grown for 1 and 2 months in 4, 6, and 8-inch long kraft paper tubes and outplanted on disked and unprepared sites revealed that no single combination of treatments was best for all species. Longleaf survival was best with 8-inch tubes planted on disked seedbed. Two-month-old slash pine seedlings survived best. Results will aid scientists in improving containerization techniques for field plantings. —SO(800).

541. Improvements of seed technology for *Quercus* species are hindered by the lack of information on maturation of the acorns. A recent study in central Mississippi has determined physical and chemical changes in maturing acorns of willow, water, and cherrybark oaks. Dry weight of the acorns watered throughout the season increased until physiological maturity was reached in late October and early November. This was also accompanied by a rapid increase in storage foods, fats, and carbohydrates. A number of indices of seed maturity were also identified which can readily be used to improve collection and storage of these acorns. —SO(802).

542. Currently accepted procedures for determining moisture content of acorns are time consuming and error prone. Moisture content of white, chinkapin, Shumard, and water oak acorns was accurately determined by oven-drying the seeds at 105°C after they had been cut into small pieces. The white oak species reached equilibrium in 8 hours; the red oak species in 9 hours. These results provide seed researchers with a more accurate procedure for measuring acorn moisture contents, and should form the basis for modifying International Seed Testing Association rules for determining moisture content. —SO(803).

543. Sandy, droughty sites are virtually impossible to direct seed if conventional methods of site preparation and sowing are used. Retention of a hardwood canopy and covering the seed with soil enhanced establishment of direct seeded loblolly pine on deep, dry sands in Louisiana; but the procedures were unreliable or too costly for operational use. Planting of nursery stock, rather than direct seeding, is the only feasible method of artificially regenerating these severe sites. —SO(806).

544. Site-species relationships must be carefully considered in rehabilitating depleted stands by planting. In 10-year-old planting trials on a variety of sites in Tennessee's Cumberland Plateau and Highland Rim provinces, loblolly and Virginia pines outgrew shortleaf pine, white pine, and yellow-poplar. Loblolly pines averaged 26 feet tall and 4.4 inches in diameter; Virginia pines 22 feet and 3.9 inches; and shortleaf pine 19 feet and 3.4 inches. White pine and yellow-poplar performed poorly. The superior early performance of loblolly and Virginia pines indicates that they should be preferred for planting on narrow ridgetops, degraded sites, and soils having bedrock or fragipans near the surface. —SO(818).

545. Cones of most southern pines are difficult to harvest because they remain firmly attached to branches when the



seed is ripe. An anatomical study of loblolly and slash pine cone pedicels at all stages of development failed to demonstrate the presence of an abscission layer, which negates the probability of inducing southern pine cone abscission with chemicals. —SO(821).

546. Broadcast sowing of southern pines requires large quantities of seed and produces stands that may be difficult to harvest mechanically. A prototype aerial row seeder, which sows three rows of seed simultaneously from a helicopter, was developed and tested. The test identified several problems which must be solved before a reliable operational aerial row seeder can be produced. Successful development of this concept will provide inexpensive and practical means of regenerating forest stands throughout the country. —SO(819).

547. Dense stands of southern pines grow slowly in diameter, which delays the time of first thinning and lengthens the rotation. Studies show that thinning to 500-700 trees per acre at age 3 or 4 years, before live crowns shorten excessively, promotes rapid diameter growth without depressing merchantable volume growth. Mechanical strip-thinning is recommended whenever live crowns of codominant trees drop to 35 percent of total height. This information will be valuable for managing dense stands of loblolly, slash, shortleaf, and Virginia pine regeneration throughout the South. —SO(791).

548. Planted northern red oak grows so slowly on cutover sites that seedlings may become suppressed by other vegetation within a few years. Weeding increased 3-year diameter growth by about 0.3 inch in two plantations on the Cumberland Plateau. A single thorough weeding was about as effective as repeated annual weeding. Height growth following weeding was reduced by about 0.1 foot per year in a 6-year-old plantation on an average site, and 0.3 foot per year in a 7-year-old plantation on an excellent site. Thus, forest managers can accelerate diameter growth of planted northern red oak by timely weeding with a relatively slight sacrifice in height growth. —SO(831).

549. Since spot-seeding of southern pines often produces clusters of two or more seedlings per spot, foresters want to know how this clustering affects stand growth. In Tennessee, the largest loblolly and Virginia pine seedlings on seedspots had expressed dominance and were 1 to 2 feet taller than their companions at 5 years of age. Moreover, dominant pines on multiple-tree spots were equal in diameter and height to comparable, more widely dispersed trees in broadcast seeded stands. Resource managers may spot seed if they choose, with confidence that stands will not require expensive pre-commercial thinning. —SO(830).

550. It is often desirable to determine if a seed is completely or incompletely developed before it is germinated or tested in other ways. A technique was developed for making stereoradiographs of individual seeds which permit detailed viewing of the seed's contents in three dimensions without destroying seed. The innovation should have broad application in education, industry, and research for detailed examinations of the interior structure of small inanimate objects of any kind. —SO(845).

551. Water oak acorns require cool, moist stratification for prompt germination. How this speeds germination is uncertain. A study of embryos from dormant, stratified, and germinated acorns revealed that stratification greatly increased development of certain organelles, such as dictyosomes and mitochondria. This new knowledge should lead to development of better, more reliable methods of storing and germinating water oak acorns. —SO(843).

552. Intensive culture will be necessary on many sites if the growth of fiber is to keep pace with future demands. A summary paper on southern pine culture is now available which suggests species to plant, site preparation techniques, spacing options, as well as alternative vegetation, water, and nutrient regulation techniques which will maximize fiber yields. This information provides land managers with alternative silvicultural approaches for growing southern pines on short rotations. —WO-TMR(834).

553. In order to supply the latest information on seeds which are the primary means for perpetuating most tree and shrub species, a new 883-page handbook has been prepared which includes seed descriptions of more than 800 species and latest directions for fruit collection, seed storage, and nursery practices. Also included are chapters on general seed biology, genetic improvement, pollen handling, and seed testing. This volume is an excellent reference for foresters, wildlife managers, nurserymen, students, and homeowners.(833).

#### Stand improvement

554. Thinning mature stands is considered to be of little value because residual trees are not expected to increase in growth rate. A commercial thinning study in 100-year-old ponderosa pine in central Oregon with from 150 to 350 stems per acre showed that losses to mountain pine beetles are reduced substantially when stands are thinned lightly but frequently from below. On good sites, these stands are also capable of growing between 700 and 800 board feet per acre per year from age 100 to at least 130 and probably beyond. Such long rotations are more esthetically pleasing than those less than 100 years because there are larger trees and fewer visually undesirable areas in a regenerating condition. —PNW(761).

555. Public concern over environmental pollution requires that managers use the most sophisticated procedures available for applying herbicides. Many specialized aerial application systems and spray additives have been developed to reduce drift of herbicidal sprays. Brief descriptions of the best available aerial spray systems, additives, and supervision necessary to insure proper use of equipment are now available to foresters. Managers must utilize these improved systems if herbicides are to continue as effective silvicultural tools. —PNW(786).

556. Well-stocked stands of young Douglas-firs are often found under dense overstories of varnishleaf ceanothus in western Oregon, but tree growth is retarded by shrub shade and competition for soil moisture. Aerial spraying with 2,4,5-T effectively released Douglas-firs, and their growth was 1.7 to 2.5 times that of comparable trees under unsprayed ceanothus. Releasing Douglas-firs from varnishleaf ceanothus can conservatively save 8 years in growing trees to a height of 20 feet. —PNW(787).

557. Single applications of herbicides often provide insufficient control of shrub species competing with desirable conifers. One respray of 2,4,5-T applied as an early foliar spray will adequately control resprouting salmonberry, western thimbleberry, vine maple, and California hazel shrubs in the coast range of Oregon. Resprays of amitrole-T or picloram do not appreciably increase degree of control over an initial application. Following these recommendations should greatly improve vegetation control and regeneration potential of difficult forest sites. —PNW(795).

558. More effective treatments are needed to prepare planting sites for reforestation and release conifers from competing brush species on high site lands in the coast ranges of Oregon and Washington. Tests show that mixtures of dicamba

and 2,4,5-T or 2,4,5-T alone are useful for site preparation as budbreak sprays. For conifer release, 2,4,5-T applied in diesel oil was effective on red alder, vine maple, and California hazel. These treatments can be used on thousands of acres of new harvest cuttings and plantations in the Pacific Northwest. —PNW(796).

559. Forest managers badly need even-aged thinning guides integrating site potential, merchantability limit forecasts, cutting cycles, and operable volume limits. Ponderosa pine thinning guides were developed in Idaho for use by foresters in estimating basal areas, stocking levels, and average spacing necessary for fast timber growth. The method appears broadly applicable to conifer forests and will increase thinning returns and improve yield predictions. —INT(788).

560. Conversion of aspen forest types to conifers is difficult because of competition from dense regrowth of aspen suckers. Burning cutover aspen stands at 2 to 4 year intervals reduced the vigor of aspen suckers in Minnesota. Infrequent burning weather, low flammability of the aspen-hardwood association, and prolific sprouting and seeding of shrubs and hardwoods make repeated dormant season burning a poor tool to convert aspen to conifers. However, repeated fall burns may be useful to maintain wildlife habitat if decreases in mountain maple and increases in hazel and willow are acceptable. —NC(792).

561. Clearcutting has resulted in numerous even-aged hardwood sapling stands in the southern Appalachian region, and means are needed to improve stand composition and maintain vigorous growth. Periodic measurements for 10 years after an intensive cleaning in an 11-year-old stand showed that crop trees had 46 percent more diameter growth and 38 percent more basal area growth in cleaned plots than in uncleared plots. The cleaning influence on diameter growth dissipated between the 6th and 10th years, however, and high initial cost, plus limited growth acceleration, suggest that early cultural treatments should be deferred until commercial stems are available. These data will help foresters decide if early cleanings can be justified. —SE(784).

562. Herbicides applied as foliar sprays to control unwanted hardwoods may drift excessively and damage nearby crops. Thickeners in spray solutions reduce drift, but their influence on effectiveness of herbicides is not known. Mixtures of thickened 2,4-D (Verton 2-D), 2,4,5-T (Verton 2-T), and Tordon K were as effective as conventional formulations of the same herbicides on mixed brush and more effective on certain hard-to-control species such as huckleberry, red maple, and flowering dogwood. Southern landowners can use these new formulations to control vegetation in situations where drift must be minimized. —SO(782).

563. A reliable method is needed for dormant season control of low-value hickories in the mountain areas of Arkansas. When injected at a 1 milliliter rate in continuous incisions or incisions 3 inches apart, Tordon 101 killed virtually all stems within 5 months. With continuous incisions, 2,4-D killed 90 percent of treated stems by the end of the second year. Cacodylic acid (Silvisar 510) and monosodium acid methanearsonate (Silvisar 550) were ineffective at both spacings. These results will help forest land managers in selecting chemicals for timber stand improvement. —SO(789).

564. Because foliar sprays may drift and damage nearby sensitive crops, other methods are needed for controlling unwanted woody plants on forest sites. In the Boston Mountains of Arkansas, soil applications of bromacil and fenuron at manufacturers' recommended rates gave consistent, reasonably high kills of red oaks. Bromacil, picloram, and M-(3,3-dimethylureido) phenyl tert-butylcarbamate applied at

recommended rates effectively controlled hickories. At one and one-half times recommended rates, all soil-applied herbicides gave high kills of hickory and all except picloram controlled red oak. None were effective at one-half recommended rates. Soil application may be a viable alternative to foliar spraying of herbicides, if higher treatment costs can be justified. —SO(790).

565. There is an extensive area of depleted pine hardwood forests in the Cumberland Plateau of northern Alabama. Nineteen years after improvement cuttings were made, stand volume increased 778 cubic feet per acre on an area where all merchantable low-volume trees were removed in a commercial cut, and 1,498 cubic feet on an area where the commercial cut was supplemented by repeated removal of cull and undesirable trees larger than 2 inches d.b.h. Unmanaged stands grew 237 cubic feet. These findings demonstrate that improvement cuttings in depleted pine-hardwood stands will increase yields, income, and forest land values provided an adequate seed source of desirable species is present. —SO(793).

#### Animal damage

566. The form of nitrogen used to fertilize seedlings in nursery beds can influence field planting success, especially if chemical composition of seedlings and deer browsing preference are variously affected. In western Washington, shoots from Douglas-fir seedlings fertilized with ammonium sulfate, calcium nitrate, or urea varied little in their chemical makeup, and the trees were equally browsed by black-tailed deer. Results indicate that the source of nitrogen applied in the nursery does not alter field damage from deer browsing. —PNW(728).

567. Sapsucker feeding in northern hardwood forests can kill birch or may slow growth and lower wood quality. A northern Michigan study found that the frequency and intensity of sapsucker feeding activity are related to crown release with the most severe damage being inflicted on the more heavily released trees. Vigorous dominant poles are fed on more often than less vigorous trees, and sapsuckers prefer yellow birch as a summer food source over all other available tree species. These results indicate that valuable sawlog sized birch should not be left along roadways, edges of openings, or isolated in thinned overstories if alternate trees will provide acceptable seed sources. —NC(724).

568. Past attempts to establish black walnut plantations by direct seeding have not been too successful because of rodent depredation. New information refutes a published report that thorough cleaning of walnut seed prior to sowing reduces rodent pilferage. However, sowing in the spring and at a distance of at least 400 feet from mature trees may help reduce predation by squirrels and increase the success of direct seeding for establishing black walnut plantations throughout the Midwest. —NC(726).

569. Regeneration failures in Allegheny hardwoods have frequently been attributed to deer browsing, but this conclusion has been based on very few data. Surveys of vegetation inside and outside deer enclosures on thirteen 5- to 16-year-old clearcuts in northwestern Pennsylvania identified white-tailed deer browsing as the cause of regeneration failures in 25 percent of the areas. About half of the areas successfully regenerated in spite of deer browsing, and other research shows that success rates are much higher if cutting is limited to stands containing abundant advance regeneration. These results clearly demonstrate that deer can be one major cause of regeneration failures in Allegheny hardwoods. —NE(725).



570. Deer browsing is a major factor limiting the success of hardwood planting in Vermont. Several mechanical protective devices were tested in a sugar maple planting of 2-year-old seedlings. None of these devices proved effective. However, the research suggested an alternative to protecting seedlings from deer browsing—using planting stock that is at least 6 feet tall. This approach could make the difference between success and continued failures in hardwood planting. —NE(729).

571. Fall-sown longleaf pine stands are sometimes heavily damaged in the first winter by rabbits that clip and eat the succulent seedlings. These losses can be circumvented by sowing in the spring, if spring germinated seedlings can withstand the harsh summer conditions. In six consecutive years, survival of pines during the first summer averaged only 4.7 percentage points lower for spring than for fall seeding. None of the annual differences were significant. Spring sowing of longleaf pine is feasible and practical where rabbit populations are apt to be high. —SO(722).

572. Although it is known that longleaf pine seeds are eaten by the red imported fire ant, the impact of their predation on the success of direct seeding has not been established. In a Louisiana study, an ant population averaging eight colonies per acre destroyed about one-third of the germinating longleaf seed sown. Damage was only slightly less to seeds coated with bird, rodent, and insect repellents than to untreated seed. Losses were uniformly high within a 20-foot radius of the nests. Populations of fire ants expand rapidly after harvest cutting and site preparation, and should be controlled by standard chemical treatments before southern pines are direct seeded. —SO(723).

#### Growth requirements

573. Many studies of photosynthesis require carbon dioxide supply systems which will respond to rapidly changing demand. One system utilizes an infrared gas analyzer to monitor CO<sub>2</sub> concentration in a cuvette. Correction volumes of CO<sub>2</sub> can be introduced at 15 second intervals. The equipment can be used by scientists studying photosynthesis where CO<sub>2</sub> concentration is critical. —NE(714).

574. In the Pacific Northwest, Douglas-fir seedlings are preferred deer forage and in many areas intensive browsing seriously retards reforestation. Chemical analyses and *in vitro* digestibility studies of Douglas-fir and other plants collected from Oregon during the winter showed that moisture content, digestibility of tissue cellulose, and overall effects of the plants' water extracts on rumen microbial activity provided the best indications of species preference. These factors could be used in ranking palatability of different plant species and possibly in selection of genotypes or strains of Douglas-fir for browse resistance. —PNW(727).

575. Lack of water frequently limits plant growth, especially in arid regions. Recent control room investigations in North Dakota suggest that water use efficiency of selected plants can be increased by growing them in greenhouses at elevated CO<sub>2</sub> levels. These conditions conserve moisture and suppress photorespiration. Water use efficiency may also be improved through genetic selection. A substantial improvement of plant water use efficiency could increase worldwide production of food and fiber. —RM(718).

576. Knowledge of DNA variation and mitotic cycle time within and among species may make it possible to predict crossability and growth potential. Research in Wisconsin found that DNA quantity per cell in red pine varied by a factor of 2.2 from the lowest to the highest amount in 20 seed sources.

DNA quantity was not related to latitude of seed source, as had been the case for some other North American conifers. The mitotic cycle was 24 hours and the period of DNA synthesis was about 19 hours. This information will help basic programs in tree breeding and form the basis for further research. —NC(689,690).

577. The expanding literature on walnut culture and use requires periodic summarization to keep users up-to-date. A newly prepared bibliography of over 220 references dealing with the growth and production of walnut provides a valuable working tool for researchers, land managers, and landowners interested in this fine hardwood. —NC(691).

578. The primary-secondary transition zone in xylem and the sequence of differentiation within this zone are not well understood. Recent research with *Populus deltoides* in Wisconsin shows that the vascular traces originate in developing leaf primordia, and in the primary zone they appear as an aggregation of discrete bundles. As each leaf matures on the shoot, the transition zone advances upward in the internode below. Because leaves are positioned helically on the shoot, the transition zone also advances helically in each internode as it matures. These results are a significant contribution to our knowledge of how wood formation occurs. —NC(703).

579. *Populus* is one of the few genera known to develop both ectomycorrhizal and endomycorrhizal associations, and this ability may contribute to its widespread distribution. In comparing the mycotrophy of five American species of *Populus*, it was found that only two of them can form either endo- or ectomycorrhizae. *Populus deltoides* readily formed both kinds of mycorrhizae, and this is proposed as a primary factor for the diverse growing habitats of this tree species in the United States. —NE(719).

580. In order to develop improved silvicultural systems, better knowledge of basic stand growth relationships is needed. The relationship of stemwood growth to leaf area index was examined in 19 managed stands of yellow-poplar in North Carolina, which had been thinned 6 years previously. Annual volume growth was found to be related to leaf area index. Thinning significantly reduced leaf area but it had substantially recovered within 6 years. These results improve our understanding of stand growth processes in yellow-poplar. —SE(705).

581. The chemical and nutrient content of fruits and seeds of many southern trees and shrubs is not known. Crude fat, protein, total carbohydrates, phosphorus, calcium, and magnesium were determined for seeds and fruits of 26 southern species. Seed of three species had protein contents in excess of 20 percent; eight other species exhibited total carbohydrate content in excess of 25 percent. This information will be useful in assaying the nutritive value of these organs for wildlife and in developing procedures for testing and storing these seeds. —SO(685).

582. Mycorrhiza, the symbiotic association between plant roots and fungi, are of great importance for successful nursery and plantation practices, particularly in afforesting denuded lands. In this pioneering PL-480 study of Indian conifers, fungal mycorrhizal associates are explored and extent of mycorrhizal development in plantations and natural forests is identified. The results will assist materially in improving Indian nursery practices and broadening our general knowledge of mycorrhizae. —WO-TMR(684).

583. The role of detoxification of indole-3-acetic acid (IAA) has been ascribed to IAA-oxidase by some and to its production of oxidation products (which cause characteristic auxin-type physiological responses) by others. A PL-480 experiment

in India using bean hypocotyls supports the hypothesis that enzymatic oxidation of IAA is essential for a positive growth response and refutes the detoxification ascribed to IAA-oxidase. —WO-TMR(693).

584. Peroxidase isoenzymes are important in plant growth and differentiation, including initiation of roots. Two specific isoenzymes (a and b) associated with root initiation have now been identified in bean plants along with another (cycloheximide) that appears to inhibit initiation. These results were obtained through an Indian PL-480 grant, and improved our ability to vegetatively root plant species. —WO-TMR(694).

585. Alternative right- and left-oriented domains occur in the vascular cambium of trees and are reflected in oblique anticlinal divisions and other growth structures. PL-480 studies with sycamore show that these domains appear during formation of the first annual ring, and their arrangement is related to stem division into nodes and internodes. These findings have expanded our basic knowledge of the process of wood formation. —WO-TMR(701).

586. Natural gibberellins (GA) apparently play a vital role in the formation of adventitious roots on willow cuttings, but the sites of synthesis of these gibberellins are not known. Studies with girdled and debudded willow cuttings at Kornik, Poland, have shown that free and bound gibberellins occur in both shoots and adventitious roots, but not necessarily the same type of gibberellin. Both tissues are sites of synthesis, and both influence the quantity and quality of GA formed in each other. These results on sites of GA synthesis will aid research efforts on vegetative propagation and the physiology of root growth. —WO-TMR(702).

587. Scotch pine, one of the world's most important timber species, is relatively slow growing during its first 2 years of development. Researchers at Copernicus University in Poland found that, during intensive growth in a seedling's first 7 or 8 days, the level of free gibberellins was high and that the level of abscisic acid-like inhibitors was low. As growth slowed after 8 days, gibberellins decreased, and abscisic acid-like substances increased. Knowledge of the interrelationships of natural inhibitors and promoters will help all research programs involved in basic studies of seedling growth. —WO-TMR(706).

588. Phenolic compounds are known to play essential roles in the processes of plant growth and development, but their relationship to endogenous plant growth regulators is not clear. Supported by a PL-480 grant, scientists in Poland have recently shown that vanillin and p-coumaric acid applied to young Scotch pine seedlings both stimulate growth. The growth stimulation coincided with an increase of auxins and with a decrease of free gibberellins in the seedling roots. Free gibberellin levels increased in the shoots. These data provide new information on the role of growth regulators in woody plants, and will help Forest Service researchers toward their goal of optimizing seedling growth. —WO-TMR(707).

589. Effectiveness of externally applied auxins in stimulating rooting of stem cuttings varies with season. Studies with *Impatiens* cuttings suggest that these seasonal variations are associated with changes in levels of endogenous auxin which, in turn, are a consequence of temperature. This basic information, developed through a cooperative PL-480 grant to India, should assist in improving our ability to root vegetative materials. —WO-TMR(712).

590. The effects of nucleic acid and protein synthesis inhibitors on root initiation are not well known. New information developed through an Indian PL-480 study of *Impatiens* hypocotyls shows pretreatment of cutting with such inhibitors breaks basal dominance resulting in root emergence all over

the hypocotyl surface rather than simply at the base. This research could be broadly applicable in reproducing difficult-to-root plant species. —WO-TMR(710).

591. Variability in rooting presents problems where vegetative propagation is to be employed. Research at Panjab University in India under the PL-480 program has shown that a proper balance between auxins and nutrition is necessary for optimal production of adventitious roots on *Impatiens balsamina*, and that this balance varies with the morphological nature of the cutting and with various environmental factors. Endogenous levels of auxins apparently exert a strong influence on the amount of IAA which is needed to stimulate root formation. This information contributes to our basic knowledge of the physiology of rooting. —WO-TMR(711).

592. Proper balance between auxins and nutrients is necessary for root initiation. A PL-480 study of isoenzyme patterns in poplar suggests a complex pattern of repression and synthesis of specific isoenzymes is associated with root initiation. Cycloheximide, which is considered to be a potent inhibitor of protein synthesis, actually induces or activates some new indolylacetic acid-oxidase isoenzymes. Results should lead to a better understanding of auxin roles in tree seedling development. —WO-TMR(1020,1021).

593. It is well known that auxins play an important role in the formation of callus tissue and adventitious root on poplar cuttings, but the mechanism of this action at the cellular level is largely unknown. Results from India have suggested that the amount of rooting is partly determined by the size of the protein and nucleic acid pools available in the tissue at the time of root initiation. The balance between auxins and the carbon pool influences both root formation and callus formation, but not in the same manner. These studies will help our research efforts on vegetative propagation of forest species. —WO-TMR(709,713).

594. Rapid progress is being made in our understanding of the factors affecting forest biology relationships, but the information is often scattered throughout scientific literature. A recent biennial symposium on forest biology included more than 40 papers from Forest Service scientists documenting "state-of-the-art" knowledge and ongoing research in such fields as forest tree nutrition, photosynthesis; growth analysis, developmental morphology, auxin relationships, moisture requirements, and tissue culture. The proceedings of this symposium provide a valuable reference tool for forest biologists concerned with fundamental aspects of forest tree growth. —PNW(716).

595. Increased knowledge of the growth of shoot apices of gymnosperms could help answer basic questions on tree growth. Recent studies in India under the PL-480 program have described major trends of specialization in shoot apices of many gymnosperms. Comparisons were made with the economically important conifer families, as well as other gymnosperms. —WO-TMR(715).

596. Seeds of the oaks are among the most difficult to store of all tree seeds. Research in Poland has indicated that the level of activity of the enzyme alpha-amylase in northern red oak is a good indicator of the general physiological state of the acorns. Amylolytic activity rapidly decreased in acorns stored at -3°C, to a level of no detectable activity after 8 months. These data provide valuable insights into physiological changes in acorns, and will aid in developing improved methods to maintain seed viability in long-term storage. —WO-TMR(717).

597. Differential response of cambium to auxin has been proposed as one cause of reaction wood. Effects of several



vitamins and chemicals which regulate cell metabolism in combination with indolylacetic acid were investigated using Scotch pine stems. Auxin did not affect cell walls advanced in differentiation, but proved essential in completing tracheid ontogenesis. Results from this PL-480 grant have increased our basic understanding of wood formation. —WO-TMR(720).

### Growth and yield

598. Loblolly pine grows well in Hawaii, but data to suggest optimum plantation spacing are needed. Measurements in plots on the Island of Maui showed that, 11 years after planting, the wider spacings continued to produce substantially larger average diameters, but less total basal area. Average diameters ranged from 6.4 inches at 6-foot spacing to 9.8 inches in the 12-foot spacing. Basal area was 168 square feet per acre at 12-foot spacing and 278 square feet at 6-foot spacing. The results will help selection of spacings on medium quality sites for various management objectives. —PSW(862).

599. Although white spruce makes up less than 4 percent of the volume of all growing stock in Black Hills forests, some white spruce stumpage is sold. Tables and equations are now available which permit estimation of total and merchantable volumes in cubic feet. Total volumes include all stemwood from ground line to tip of tree, while merchantable volumes include stemwood from a 1-foot stump to a 4-inch d.i.b. top. Data will permit managers to evaluate and equitably market white spruce. —RM(852).

600. Under present utilization standards, many of the Nation's fine hardwoods, such as black walnut and yellow-poplar, have little or no value if they are smaller than sawlog size, resulting in considerable waste when immature stands of these species are thinned. Small diameter trees removed during thinning operations in southern Illinois were successfully converted into furniture dimension material. As much as 2000 square feet per acre of 1-inch material suitable for manufacture into furniture can be produced from intermediate thinnings. Use of thinning residue for dimension material could increase the supply of all lumber grades and help conserve the rapidly dwindling supply of high-quality hardwoods. —NC(855,859).

601. Control of stand density through thinning is one of the most feasible ways of achieving many objectives of forest management—if the response to thinning is known. Data from 141 natural yellow-poplar stands in the Appalachian Mountains of Virginia, North Carolina, and Georgia have provided equations which describe growth and yield in response to thinning. Maximum board-foot and diameter growth were obtained at considerably lower densities than needed to produce maximum cubic-foot volume. These guidelines should prove valuable to resource management making decisions on treatment of natural stands of yellow-poplar. —SE(853).

602. The biological potential for forest ecosystems is needed to determine availability of timber now and in the future. For the loblolly pine ecosystem on 12.4 million acres in the Southeast it was estimated to be 1.2 billion cubic feet of net annual growth per year. To achieve this biological potential, the most important action programs should be to assure the reforestation of every harvested loblolly pine to full stocking. A most important research effort should be to find inexpensive ways to rapidly reforest harvested loblolly pine stands. —SE(854).

603. Projected demands for pulp and paper products indicate an important need for methods of increasing productivity on forest lands. Yields and other stand data from two coppice plantations of sycamore in Georgia have indicated a

potential threefold increase in wood fiber production over conventional regeneration and management methods. Spacing of 4 x 4 or 4 x 6 feet should be favored for 3- to 5-year cutting cycles. This short-rotation coppice method could lead to significant increases in fiber production, and it may be applicable to other species and regions. —SE(857).

604. Little is known about growth rates of longleaf pine plantations under varying intensities of management. In an unthinned east Texas plantation, where site index averaged 83 feet at 50 years, merchantable yields at age 25 ranged from 18 to 45 cords per acre, and increased with increasing basal area. Periodic annual growth after thinning increased directly with residual stocking and exceeded 2 cords per acre if basal area was greater than 70 square feet. Diameter and volume growth of individual trees declined as initial diameter of the tree and basal area stocking increased. Equations were developed which predict growth rates of individual trees and stands. This information will enable landowners to select residual densities for longleaf pine plantations that best fit their management goals. —SO(858).

605. Resource managers need accurate information on expected yields of southern pine plantations to guide them in deciding when to harvest planted stands and whether or not to establish new plantations. Growth models and yield tables were developed for loblolly and shortleaf pine plantations in the Tennessee, Alabama, and Georgia Highlands which show expected cubic-foot yields, basal area, height, and trees per acre by 1-inch diameter classes for likely combinations of planting density, site index (base age 25 years), and age from seed. —SO(860,861).

### Forest measurements

606. Existing cubic-foot volume tables are inadequate to accurately predict growth in young Douglas-fir stands. Stem analysis data were gathered from Oregon, Washington, and British Columbia and two volume equations derived. One equation is for trees 6 to 18 feet in height and has a data base of 59 trees. The other equation is for trees larger than 18 feet in height and has a data base of 1068 trees. Volume tables were prepared from these equations using a new technique that will insure managers close and consistent estimation of cubic-foot volume of small trees. —PNW(866).

607. Some foresters anticipate the change to metric measurement as a potential disaster. A recent paper presents history of the metric system and metrication in other countries. Results should reassure the previously uninformed that all we face is an easier and more efficient measurement system. —PNW(865,877).

608. Douglas-fir has a different height growth pattern in high-elevation Cascade Range forests than that shown by existing site and yield tables, all of which are based on low elevation stands. For a given height at age 100, early growth is slower, and growth is sustained to greater ages at high elevations. Thus, yield estimates derived from low elevation stands are not applicable. New site index curves derived from stem analyses of 52 trees provide a more accurate basis for Douglas-fir site classification and growth prediction at high elevations in the Pacific Northwest. —PNW(869).

609. Conventional site index curves may not always be the most efficient method of estimating tree height-age relationships. Regressions of height on age and site index on height and age, derived from noble fir, Douglas-fir, and red alder stem analysis data in the Cascade Mountains of Washington and Oregon, showed significantly different curves. It is concluded that conventional curves having height as the depen-

dent variable should be used to construct yield tables. Curves having site index as the dependent variable should be used when the purpose is to estimate site index or future height from measured present height and age. —PNW(868).

610. Spatial distributions of redwood seedling and sprout regeneration are different and require different sampling methods to estimate stocking. A combination sampling method of milacre quadrats for seedlings and point-samples for sprouts was proven successful in a clearcut old-growth redwood stand in northern California. The variation in estimates of the number of sprouts per acre by point-sample was much less than variation in estimates by quadrats. An estimate of future sprout stocking was made by assuming a crop tree from each redwood clump and then comparing estimated number of crop trees per acre with yield tables. This technique allows improved estimates of stocking for the future forest crop. —PSW(872).

611. Statistically-rigorous procedures for modeling probability of mortality for individual trees have not been available to forest researchers. A mathematical problem-solving rule from the biomedical field has been adapted to forestry use by introducing techniques to handle data sampled with unequal probability. In addition to modeling probability of tree mortality, the procedure has also been used to predict the presence or absence of cull in trees and to investigate the levels and trends of natural inactivation of white pine blister-rust cankers. This procedure can be applied to other situations in which the response to be predicted is dichotomous. —INT(871).

612. Interest in and probability of adoption of the metric system has created a need for expressing forestry measures in metric units. Existing tree volume equations for major Rocky Mountain and Southwestern species have been converted to metric equivalents. A simple procedure for converting any tree volume equation of the form  $V = a - b D^2 H$  has also been developed. This research will help foresters become accustomed to familiar relationships in metric units and start adapting computer simulation programs and other management tools to their use. —RM(873).

613. Foresters often need to know the size of individual trees which have been removed from cutover stands. If pre-cutting measurements are lacking, key dimensions of missing ponderosa pine trees can be estimated using new aids. In the Black Hills of South Dakota, tables and equations permit direct estimates of diameter at breast height, outside bark, from inside and outside-bark diameter of stumps 0.5 and 1.0 foot high. If stem volumes are needed, heights of missing trees can be estimated by determining the diameter-height relationship for trees in the immediate vicinity. —RM(876).

614. Prediction of growth under various stand and site conditions is a prerequisite for knowledgeable management. Multiple regression techniques were used with data from thinned stands of yellow-poplar in North Carolina to relate growth of individual trees to several readily measured parameters of tree and site. The best equations accounted for approximately 50 percent of the variation in diameter growth. Of the competition indices tested, none proved substantially better than average basal area per acre. These results will aid in further studies of stand growth and how its measurement may be improved. —SE(863).

615. Because chips from slabs and edgings are valuable byproducts of modern sawmills, methods are needed for estimating volumes of these residues in logs and standing timber. The International and Scribner log rules have been adapted to estimate kerf and slab-edging volumes as well as lumber

volume in logs. As reliable taper curves become available for individual species, the technique can be used to construct volume tables and compute yields per acre of lumber, slabs, edgings, kerf, and topwood. —SE(864).

616. Processing of mensurational data collected using different sampling systems and measurement techniques is a continuing problem. An improved program is now available for using dendrometry data from individual or clusters of trees selected by means of a variety of sampling designs to provide estimates of volume, surface, length, product, and value. The use of this Georgia research will result in more efficient processing of large amounts of data used in forest inventory and timber appraisal. —SE(870).

617. Whenever predictor variables in a regression analysis are highly correlated, regression coefficients determined by the process of least squares are unreliable. New research extends the techniques of ridge regression so that prior information on parameters can be accommodated. Estimators are unbiased if the prior information is unbiased. The techniques given have potential application whenever regression analyses are conducted in the presence of prior information on the regression coefficients. —SE(874,875).

### Management planning

618. Good resource management decisions require sound quantitative data from the management unit. Manual extraction of this data from photographs and maps is slow and expensive, but computerized mapping offers a greatly improved system for this task. A recent comparison of manual and automated digitizing procedures suggests that investment in automatic map digitizing hardware will substantially reduce data collection costs per acre for a large workload. The gains from such a geographic information system offer forest managers expanded and improved bases for management decisions. —PSW(879).

619. Natural catastrophes, such as wildfires, create sudden changes in forest conditions. Forest type, location, and boundaries must then be replaced with new information. A new method of acquiring locational information has been tested on the Stanislaus and Eldorado National Forests in California. This computer-based system permits easy maintenance of a current data base and avoids the necessity of acquiring completely new data periodically. —PSW(884).

620. Height increment is difficult to measure accurately on standing trees; however, it is a major component of forest growth calculations that are needed for timber management planning and reviews of timber resources. Directly measured height increments on 1,185 felled trees were analyzed to develop prediction equations based on tree height, diameter, and radial increment for 10 species of trees growing in 10 habitat types of the northern Rocky Mountains. These prediction equations will assist managers in estimating forest growth and yield. —INT(887).

621. Large areas of old-growth spruce-fir forests in the central Rocky Mountains are being converted to stands that must be managed from the regeneration period to harvesting. To assist in making management decisions in this region, a new computer program, SPRYLD, has recently developed which can produce yield tables for managed even-aged Engelmann spruce-subalpine fir stands at a cost of only 8 cents each. Large numbers of tables can be computed based on combinations of site quality, frequency and intensity of thinning, regeneration system, rotation length, and utilization standards. With the new computer program, a manager can examine a set of yield tables to assess probable results of his proposed



operations and make necessary changes in management goals before operations are carried out in actual forest stands. —RM(878).

622. Land managers and land use planners must know the available multi-resource options and the long term consequences of decisions made on forest areas. A model has been developed for the central Rocky Mountains which simulates timber yields and determines changes in snowmelt and water yield resulting from harvesting timber. Hydrologic changes and timber yields can be determined for a few years or an entire rotation of subalpine forests (120 years or longer). Land managers now have a decisionmaking aid that can be used to project probable changes in snowmelt, water yield, and timber growth and yield following timber harvesting in lodgepole pine and spruce-fir forests. —RM(881).

623. Many systems designed to provide information useful in land-use planning or resource management are not cost-effective because it has not been clear just how the information is to be used. A recently described decision framework for management provides new guidelines on how the information should be used. The new decision framework suggests that inventory system designs should carefully specify objectives, consider the value of information in the sense of losses incurred as a result of inadequate information, and be aware of advanced principles and current alternatives. Both land managers and inventory design specialists can use this framework to be more cost-effective in designing resource inventory systems. —SE(889).

624. Resource managers and inventory designers are continually facing rapidly increasing costs of information gathering, increased demand for resource stock and productivity information, and alternative approaches to inventory. A systems-analytic assessment of: (1) Information needs; (2) properties of sample selection rules, estimators, and measures of reliability; and (3) cost effectiveness analysis of alternative sampling schemes has been proposed. Examples of such assessment relate to equal and unequal probability, 3-P sampling, sampling with partial replacement, and other sampling schemes which might be used for simultaneously estimating growth and current inventory. Results will assist inventory designers to control costs of obtaining information of required reliability and to assess this reliability. —SE(888).

625. Accurate and comprehensive information on natural resources is essential for rational land-use planning. The Puerto Rico Natural, Cultural, and Environmental Resources Inventory used black and white aerial photography, simple photo interpretation techniques, and a computer program to develop a data bank from which information can be retrieved by conventional overlays, computer-drawn maps, or tabular outputs. The data bank can easily be expanded or updated as additional, more complete, or more accurate information becomes available. This method can be used by government agencies and private groups for overall land-use planning, as well as for a variety of immediate practical projects. —ITF(882).

### Maple syrup production

626. Both parental and clonal stocks are needed in a program for the genetic improvement of sugar maples for sap-volume production, to assist maple syrup producers in satisfying the increasing demand for their product. Phenotypic selections were made among sugar maples in eight of the important syrup-producing States. In the first year of the program, 55 superior sap-producing trees out of 2,375 tested were found that have potential as parent stock and clonal material in the improvement program. —NE(947).

627. The lack of an easy method of comparing sap volume production between trees has long stymied phenotypic selections of sugar maples for superior sap volume production. In recent research in Vermont, high correlation has been found between sap-flow rate and total sap volume produced during the sugaring season regardless of whether trees were single- or multi-tapped. Measurements of sap-flow rates in conjunction with other parameters can now be used in developing criteria for making plus-tree selections for super sap volumes. —NE(949).

### Naval stores

628. In the last few years, a number of improved, modern methods have been developed to benefit both the gum producer and the timber owner. These are now described in a new booklet which details recommended procedures for maximum gum production. By following the various recommendations, chipping-labor requirements can be reduced by 50 percent and many otherwise worked-out trees can be made salable for other wood products. —SE(951).

629. Removal of the rough outer bark of slash and longleaf pine prior to oleoresin collection is a difficult and time consuming job. A rossing tool powered by a lightweight chainsaw motor has now been developed, which prepares a smooth seat for attaching tins and cups and makes chipping of streaks easier for the workers. The motorized tool is practical and readily adaptable to woods conditions in the average commercial naval stores operation. Mechanical power eases the hard physical work of rossing trees and is 60 percent faster at the tree than the handtool; man-day accomplishments are substantially increased. —SE(953).

630. Successful use of acid paste to prolong gum flow requires application of the correct amount of paste to freshly chipped streaks. A new stainless steel tip has been developed to add to the nozzle of acid paste bottles which improves the efficiency of the acid paste. Because workers will not be able to reach out or enlarge the steel opening, the new tip should help prevent overtreatment and should last a minimum of 1 year. —SE(952).

631. Mechanical wounding and chemical treatments are commonly employed to stimulate oleoresin production of southern pines. Recent studies of wood around resin chipping wounds showed an increase in the abundance of tyloses, which are outgrowths of the parenchyma cells into a tracheid cavity. An exception was paraquat treatment which appeared to restrict tyloses formation. Tyloses in pines are not common, and this appears to be the first such report of tyloses in stemwood of pines with pinoid pits. —SE(954).

## Breeding Improved Trees

### Inherent variation

632. Selection of zones for provenance trials and plantations can be inefficient if based on trial and error. Data from an extensive Scotch pine provenance test in Sweden were used to develop a model based on the concept that species developmental cycles should match seasonal cycles for adaptation in high latitudes. The model indicated that the area suited for plantation zones for Scotch pine on severe sites may be only 5-10 percent of the area suitable for plantations on mild sites within the same geographic region. This information can be extremely useful in the planning and interpretation of provenance trials in the northern U.S. —PNW(892).

633. In cases where local seed is not available for regeneration programs, the limits to which non-local sources may be used should be known. Research in Oregon with 44 provenance collections of Douglas-fir from the Northwest used models to predict timing of vegetative bud burst in seedlings. The prediction equations suggested that moving seed in east-west directions is likely to be more maladaptive than moving seed an equivalent north-south distance. These results can aid decisionmaking in regeneration programs where seed source is a vital question. —PNW(891).

634. Ponderosa pine in California grows on a wide variety of soils ranging from highly infertile, ultramafic soils, to highly fertile, granitic soils. Seedlings of selected, wind-pollinated ponderosa pine showed large between-family differences in growth and survival on infertile soils. The families showing the greatest growth were more efficient in taking up calcium, the element in which ultramafic soils are characteristically deficient. These results clearly show that only ponderosa pine families with proven adaptation to specific soil conditions should be used in reforestation infertile soils. —PSW(898).

635. Accelerated artificial regeneration of Douglas-fir in the northern Rocky Mountains requires an expanded knowledge of patterns in genetic variability for use in delimiting seed zones. New data indicate a high degree of variability in Douglas-fir populations in this region. Populations are not systematically differentiated by topography (drainage, slope, and aspect), but are correlated with broad geographic areas and with specific habitat types. The valuable conclusion for foresters is that seed zones can be more accurately defined and yet broader than previously anticipated. —INT(906,907).

636. Aspen clones growing side by side often show substantial height differences which may be an important selection criterion. Height over age curves of dominant trees were compared for five pairs of adjacent clones by destructively sampling 70-year-old aspen stands in Arizona. Height growth differences between clones at age 30 or younger may sometimes be reversed. Aspen planting programs should take advantage of clones with superior growth potential as well as other inherent differences, but clonal material should ordinarily be collected from stands over age 30. —RM(816).

637. It is possible that there are strains or races of ponderosa pine from sources outside the Black Hills which possess traits making them superior to local growing stock. Seedlings representing 75 provenances in the eastern portions of the species' range were planted on the Black Hills Experimental Forest. After 5 years on a better-than-average site, no trees from other provenances survived better or grew taller than comparison trees from the Black Hills. Trees from some sources in Wyoming, eastern Montana, Nebraska, and North Dakota showed enough promise to warrant continued study, and perhaps more widespread testing. In time, some of these trees may reveal characteristics of growth, quality, or pest resistance which would make them desirable for breeding and propagation. —RM(914).

638. Selection of suitable geographic seed sources is the first step in a tree improvement program. In one Maryland planting, local black walnut seedlings were taller than those of 12 out-of-state sources after 5 years. Genetic influence on height growth was expressed early with little change in ranking after the third year. Seedlings from south-of-local sources outgrew trees from northern sources indicating that seedlings originating north of Maryland should not be used to establish plantations in that State. —NC(903).

639. Genetic improvement in forest trees is a slow process due in part to the long time required for selected progeny to

mature and produce seeds. In a recent study on the Allegheny National Forest in Pennsylvania, it was found that nitrogen and phosphorus fertilization stimulated early flowering of black cherry seedlings in a 2-year-old seed orchard. Growth was also increased, suggesting that, by proper fertilization, the time required for black cherry to produce seed can be greatly shortened. —NE(894).

640. Interspecific hybridization can provide the wide diversity of genotypes needed for maximum genetic improvement with trees. The genus *Populus* offers far greater possibilities for genetic improvement than any other genus of forest trees because of the diversity of the genetic resource, species crossability, possibility of clonal propagation, simple controlled breeding methods and other factors. Poplars can be bred to order for timber and veneer production, fiber crops, or amenity plantings. —NE(911).

641. Early selection is an important factor in any tree improvement program. With hybrid poplar clones grown in New England, early selections based on total height at 1 or 4 years may result in negative selection differentials at age 15. These results suggest that when genetic correlations between early and mature performance are low, a reduced selection intensity may be the only way to preserve the best clones at age 15. —NE(918).

642. Tree improvement efforts in the Southeast have as their goal the production of rapid-growing, disease-resistant trees with straight boles and compact crowns. To examine the effects of these efforts, 10-year-old trees from a heritability study of loblolly pine were chosen to represent extremes of stem straightness, branch size, and disease incidence. Results indicate that wood from straight, small-limbed trees yields significantly more pulp of greater resistance to tear than does wood from crooked, large-limbed trees. Fusiform rust-infected wood yields significantly less pulp with lower burst and breaking length than does rust-free wood. —SE(890).

643. Slash pine is one of the most valuable of the southern pines and a species in which genetic improvement is rapidly taking place. For example, major emphasis of range-wide slash pine improvement programs is on improving growth rate, tree form, oleoresin yield, and resistance to fusiform rust. Other efforts are directed toward improving seed quality. The state of genetic improvement as well as the distribution, taxonomy, pollination, techniques, growth, and survival rates are now summarized and evaluated for those planning to use this species. —SE(893).

644. Outstanding individual trees of *Eucalyptus robusta* introduced into Florida before the turn of the century have potential for timber production, even though volume growth of average trees is marginal for industrial pulpwood plantations. One generation of selection within 57 open-pollinated families in a species introduction arboretum produced a 68 percent increase in volume of individual trees. The eventual conversion of the progeny test into a seed orchard will provide genetically improved seed to the public for planting on acid flatwoods and dry prairies of south Florida. —SE(895).

645. Most pine breeding programs in the South are currently based on phenotypic selection of individual trees of only local origin. New provenance research results in Georgia with loblolly pine at 15 years of age indicate that tree breeders throughout the South should increase their emphasis on geographic variation to obtain additional gains from individual tree selection. Selections should be made among provenances first and than among mother trees within provenances. —SE(901).



646. Forest tree geneticists usually assume that the genetic correlation among offspring from an open-pollinated tree is .25, but this assumption may cause bias in estimates of heritability and genetic gain. A recent analysis of this problem using a range of hypothetical conditions suggests that correlations under real situations will usually be appreciably larger than .25. In most forest tree populations, the use of .25 as the correlation will result in a net overestimate of genetic variance and heritability. An awareness of this bias can help the planning and operation of tree improvement programs. —SE(912).

647. New studies with cottonwood indicate that, with the exception of first-year height, predictions of genetic growth response from single sites were not widely different from predictions based on three sites. Genetic gains that can be obtained are 9 percent for height, 21 percent for diameter, and 8 percent for specific gravity. Estimates of genetic parameters will be useful to cottonwood breeders, and the gain in growth can be utilized by commercial growers. —SO(905).

648. Seed production is of primary importance to the success of tree improvement programs. Considerable disagreement exists in the world literature as to factors that enhance seed production in conifers. A recent synthesis shows that most observed responses can be explained on the basis of enhanced nitrogen availability at the critical period of strobili initiation. Yet, genetic control of fruitfulness is crucial, and must still be considered in planning future experiments. —SO(910).

649. Grafted pines have been used in the past to evaluate the inheritance of cortical terpene composition without any real knowledge of possible rootstock effects on terpene composition. Scions of three loblolly clones were grafted on five southern pine rootstocks. Gas chromatographic analysis of scion cortical monoterpene showed a negligible rootstock effect with clonal effects being large. Thus, current estimates of heritabilities based on grafted pines are essentially accurate. —SO(909).

650. Determination and preservation of natural genetic variation in tropical and subtropical tree species is urgently needed, before the existing wild stands are destroyed. In a study of 16 *Pinus caribaea* provenances in Puerto Rico, the mean hypocotyl lengths of newly germinated seedlings were found to be statistically different. These differences apparently represent true genetic variation. Such traits may be useful in detecting genetic variation between provenances of this species. —ITF(915).

651. The tree breeder and forest geneticist need a broad general knowledge of the taxonomic relationships, reproductive behavior, and genetics of tree species they are working with. Information on these essential characteristics and extent of breeding and tree improvement programs are now available for five important species—Sitka spruce, blue spruce, pitch pine, Virginia pine, and chestnut. These syntheses should prove of major value in development of tree breeding efforts. —WO(896,897,900,902,908).

#### Insect-disease resistance

652. Leaf rust can seriously limit yields of poplars grown under intensive culture for pulp. Plantings of poplar clones at Rhinelander, Wisconsin, have shown that *Melampsora medusae* leaf rust may be a threat to maximum fiber production because it reduces the photosynthetic area of leaves and causes premature defoliation. Out of 32 different *Populus* clones tested, degree of resistance varied from total resistance to severe susceptibility. Thus, candidate clones of poplar

should be screened for rust resistance early in the selection process, and such resistance incorporated into clones selected for propagation. —NC(501,921,924).

653. Southern pine seed orchards are not producing nearly as much improved seed as they could. Recent studies in the South indicate that less than 25 percent of the potential seed production is being obtained. Good gains could be achieved by better control of the insects which feed on seed. A reasonable goal for seed efficiency is 80 percent for seed orchards with adequate insect controls. —SE(919).

654. First-year conelet abortion in southern pines may reduce the potential crop of mature cones 50 percent or more. Pollen deficiencies and the feeding of seedbugs are major causes of abortion. Feeding on ovules by seedbugs in spring and early summer causes much of the conelet abortion in seed orchards previously attributed to inadequate pollination. Recognition of this fact should stimulate much needed research to develop methods for controlling these important seed insects. —SE(923).

655. Tree hosts for the large 1963-66 epidemic of the Scolytid, *Dendroctonus frontalis* Zimm., in Honduras, C.A., have now been morphologically confirmed as *Pinus oocarpa*, *Pinus caribaea* var. *hondurensis*, and *Pinus tenuifolia*, and not *Pinus pseudostrobus* as heretofore supposed. Little or no hybridization between the three pines was observed. Xylem oleoresin monoterpenes were useful for differentiating among host species, but no consistent terpene differences were found between supposedly beetle-resistant trees and check trees of each species. —SO(920).

656. Artificial inoculations are used to identify loblolly and slash pines resistant to fusiform rust. A technique employing suspended telia-bearing oak leaves has been used widely, but it and other available methods lack the flexibility necessary for automation as well as control over inoculum density and source. A more efficient spray technique has been developed, and results with it correspond closely to those after exposure via the oak leaf technique. This agreement, and its greater flexibility in terms of inoculum source and density as well as its ease of automation, qualify the spray-inoculum source technique for use in large-scale resistance breeding programs. —SO(922).

657. Selection of fusiform rust-resistant pines in the southern United States has been greatly aided by the development of artificial inoculation techniques. Samples of loblolly pine seedlings from Arkansas, Louisiana, and three places in Alabama were artificially inoculated with fusiform rust at ages 6 weeks and 1 year, and then planted in southeastern Louisiana and central Mississippi. Progenies ranked the same in terms of field infection as when artificially inoculated at age 1, but artificial inoculation of 6-week-old seedlings resulted in heavy infection, largely obscuring genetic differences among progenies. Control of inoculum density seems a necessity if artificial inoculation of 6-week-old seedlings is to be a reliable indicator of field performance. —SO(925).

#### Tree breeding methodology

658. Douglas-fir grafts in two Oregon and two Washington seed orchards were leader-pruned for six successive years to find out if height could be desirably controlled without reducing cone production. Results indicated height growth control reduced cone production in direct proportion to reduction in tree height. In order to provide a large crown surface for cone production, it is recommended that trees be permitted to grow at least 15 to 20 feet tall before annual or biannual pruning is started. —PNW(932).

659. Grafting is an essential technique in Douglas-fir tree improvement; however, Douglas-fir commonly rejects grafts other than its own tissue. Investigations of the inheritance of graft compatibility have now determined that multiple genes must be involved because compatibility is transmitted in an additive manner. With this new data, the seed orchard manager working with the tree breeder should be able to select highly compatible rootstocks for seed orchards. —PNW(933).

660. When ponderosa pine and Douglas-fir flowers were pollinated with their own pollen, the resulting seedlings were often smaller and had more cotyledons. In addition, seedlings resulting from controlled crosses were invariably larger than wind-pollinated seedlings. The superior growth of controlled crosses appears to be due to the more favorable cone and seed environment in the pollination bag. These growth differences could contribute to major errors in interpreting results of genetic tests, and tree breeders should be aware of them. —PNW(943).

661. Hybridizing different species of pines can result in trees with new and useful combinations of growth characteristics. The California Christmas Tree Growers, in cooperation with the Forest Service, produced and tested an artificially-produced hybrid between lodgepole pine and shore pine. After 5 years of field testing, results were mixed—some growers found the hybrids very useful, others found them worthless. Continued testing of new hybrids and selected species is needed to produce improved types of Christmas trees. —PSW(937).

662. A single 3000-year-old bristlecone pine that produces only white pollen was found in the White Mountains of California. The only other known example of a conifer producing white pollen is *Pinus resinosa*. By using pollen color as a genetic marker, studies with this unusual individual can contribute to our understanding of important developmental processes in trees. —PSW(899).

663. At what age is selection meaningful? New information from northern Idaho shows that selection for ponderosa and western white pine growth is not very reliable until the progeny are 15 to 20 years old. However, limited culling for poorest provenances or families could begin at about 10 years of age. Results indicate that, in the Inland Empire forests, tree breeders and forest managers must exercise caution in early selections. —INT(946).

664. Additional information concerning the patterns of genetic variation in western white pine is needed in order to accelerate the tree improvement program of this species. Identification of inheritance of single-gene traits is an approach to recognizing more complex traits. In an Idaho study, the presence or absence of a purple coloration of one cone was identified as a single gene. The next step is to correlate this gene and other known single genes with various characteristics of economic importance. —INT(945).

665. Efficient systems are needed to select trees or families for several desired traits simultaneously. A new system is proposed that employs: (1) Multiple counting and selection; (2) selection for the best trees on the basis of single traits, and (3) inter-trait correlations based only on families that are selected. When data were collected on flushing date, diameter, height, straight height, and number of leaders competing for dominance in two black walnut seed orchards in southern Illinois, the applicability of the new system could be demonstrated as a useful guide for selecting improved seed. —NC(927).

666. Grafting of one tree species onto another may stimulate early seed production. In a southern Illinois study, greenhouse grafting was at least partially successful for all combinations of three walnut species, and eight species and hybrids used as top or scion material. All grafting methods and graft wrapping materials tested were reasonably satisfactory; the techniques may be useful in establishing seed orchards. —NC(938).

667. The major cause of empty seed in Virginia pine appears to be embryonic lethal alleles when insect damage is eliminated. A study in the Virginia Piedmont showed that embryonic lethals in Virginia pine greatly reduce filled seed percentage following self-pollination. Seed orchard trees should be evaluated for the presence of lethal alleles, so that action can be taken to correct this problem. —SE(929).

668. Substantial losses of Virginia pine seed occur during maturation. Recent studies in Virginia have shown that, starting with a potential of 85 seed, only 23 percent filled seed were produced. Suggested causes of ovule and seed losses are insufficient pollen, insects, and embryonic lethal alleles. Most seed loss was apparently due to insects. Screen wire cages could be used to protect high value, control pollinated cones. —SE(928).

669. Choctawhatchee sand pine rootstocks are preferable for sand pine seed orchards, but grafting onto these rootstocks has been difficult. For a high proportion of grafts to succeed, both scion and the rootstock plants should have broken dormancy when the grafts are made. Scions should be gathered when terminal buds just begin to elongate and rootstock seedlings should have from 2 to 4 inches of new terminal growth. These techniques have resulted in 60 to 75 percent success as contrasted to 25 to 35 percent success when dormant scions and rootstocks were used. This information will greatly simplify the establishment of sand pine seed orchards. —SE(930).

670. Means are needed to improve pollination in seed orchards and increase yields of cones and filled seeds. Studies with slash pine in Florida have indicated that mass artificial application of pollen may help solve this problem, and that cross-pollen may have an advantage over self-pollen because of timing and embryonic competition. The first pollen applied always accounted for most of the resulting seedlings, but self-fertilized embryos were at a disadvantage when competing with cross-fertilized embryos. These results will be useful in formulating guidelines for mass artificial pollinations by orchard managers. —SE(935).

671. In order to test the value of individual tree phenotypic selections, some pine breeding programs are using a four or five male tester procedure. Recent data from 6-year-old single cross progenies of slash pine in Georgia show that, because of the relatively large proportion of genetic variance resulting from general combining ability effects, parental breeding values can be more cheaply estimated from progeny tests of open-pollinated or polycross seeds. —SE(939).

672. Tree breeding strategies necessarily require the breeder to choose among breeding and selection programs which vary in the amount of immediate genetic gain and the amount of gain which can be accumulated in future breeding generations. The two elements can be shown as functions of the effective parental population size. A new concept of a population rental is introduced, and an optimizing function is proposed. With this concept, planning for national or other long-term breeding programs can be based on a rational function which balances present genetic gain and future genetic opportunity costs according to an interest rate. —SE(941).



673. To maximize genetic gains per unit of time, tree breeders must utilize the results of progeny tests as soon as relative performance can be reliably predicted. Periodic measurements of stem growth and oleoresin yield in a slash pine progeny test in Florida showed weak correlations between measurements taken at 3 and 25 years. Correlations increased rapidly for subsequent measurements at 8, 14, and 18 years, however. The results indicated that the greatest genetic gain per year would be obtained by selecting at 10 years and by permitting a generation interval of about 14 years. —SE(944).

674. Tree improvement workers frequently use vegetative propagation techniques to increase material with desirable traits. With a new propagation method developed in Mississippi involving both environmental and chemical treatments, 83-100 percent of cuttings from pines up to 13 years old rooted in 6 to 12 weeks. A combination of auxins, sucrose, a fungicide, and a growth retardant induced the best rooting. If similar results are obtained in greenhouses, such treatments will find wide application in many phases of tree improvement research and practice. —SO(936).

675. Maintenance of germ plasm and narrowing of the genetic base are serious problems in highly-bred agricultural crops. Are there similar problems with forest trees? Based on a status review of forest tree breeding and efforts to preserve natural populations in place, the risk of significant loss of forest tree germ plasm seems small in the United States. Problems do exist in other countries, and forest geneticists must remain very conscious of risks to continued genetic diversity from tree breeding efforts. —WO-TMR(926).

## Improving Uses and Protection of Wood

### Utilization potential and processing of wood

676. It needs to be determined whether aerial row seeding is ready for commercial operations. Results of tests showed that aerial row seeding rates were too low, ranging from 542 to 3042 seeds/acre. Row spacing was erratic, but precision sowing from altitudes of 50 feet or less seems attainable. Areas of needed improvement were identified. An aerial row seeder is approaching practical usage although there are needed changes. —SO(1131,1147).

677. Removing a streak of bark and applying acid paste to stimulate gum flow from the living pine tree is the phase of gum harvesting requiring the highest level of skill and the greatest physical effort. A hydraulically-powered implement which can remove the bark streak and apply the acid paste automatically has been designed and a prototype fabricated and laboratory tested. If upcoming field tests are successful, the implement has the potential to reduce the skill level of the labor required and to increase the number of streaks removed per unit of time. —SO(1152).

678. Drying southern pine at high temperatures is becoming a standard practice, but some inefficiencies exist because basic principles are not well understood. Success in high temperature drying of thick veneers, lumber, timbers, and poles depends on moisture content variation, restraint during drying, air velocity, board thickness, temperature, and wet bulb depression. Understanding these factors will result in less loss during drying. —SO(1143,1200,1201).

679. Warp in kiln-dried southern pine causes very substantial degrade and loss of lumber value. A continuous kiln that provided complete mechanical restraint against warp brought pieces to 8.3 moisture content in 24 hours without casehardening and only half the warp found in conventional drying

methods. These findings will stimulate commercial kiln manufacturers to improve their design. —SO(1202).

680. In conventional kiln drying with smooth sticks separating lumber courses, failure to restrain shrinkage stresses can result in warped lumber. Sharply toothed aluminum kiln sticks restrained the lumber during drying resulting in a straighter, more uniform product. This research suggests new practices can improve the quality of kiln-dried lumber. —SO(1204).

681. Closer utilization of trees and logging residues alters both net dollar returns and non-dollar costs and benefits. In a study of alternative levels of wood resource utilization in mature lodgepole pine, both dollar and non-dollar effects were evaluated. Net dollar returns were greater in conventional logging (removal of green sawlogs to a 6-inch top, with slash piled and burned) than in near-complete harvesting (sawlog removal followed by field chipping of remaining wood material on the site). However, substantial non-dollar benefits were gained by near-complete harvesting, especially in esthetics, fuel reduction, and site preparation. Continuing studies of harvesting influences upon soils, hydrology, nutrients, and regeneration will further define costs and benefits, and will provide managers with guidelines for harvesting practice decisions. —INT(1124).

682. Energy derived from wood residues seemed best suited for inplant steam and power production by the wood industry. It is possible that the production of high-value products or public absorption of the extra cost of utilization can make the other noted residue management alternatives more feasible. —PNW(1186).

683. The increased need for world pulp production has focused attention on forest residues as a source of fiber. Changes in timber sales procedures, such as negotiated lump-sum sales, service contracts, and compound contracts, are proposed and considered essential to facilitate more complete utilization. This study reports eight advantages to more complete timber utilization on the Pacific Coast. —PNW(1185).

684. Better techniques are currently available to determine the total amount of wood contained in sawtimber size trees. If industry is to improve its utilization practices, it must have improved methods of estimating the wood contained in the main stem as well as other parts of the tree. Timber buyers and sellers can use regression equations to estimate the amount of wood and bark in the main stem, as well as the small, medium, and large branches of lobolly pine trees. This will enable both buyers and sellers to appraise prices for all wood being sold. —SE(1244).

685. Through the use of computer simulation, a log can be "sawn" many different ways. Computer simulation provides statistically reliable comparisons of yields among various sawing methods. This technology allows sawmills to increase yields from short low-grade hardwood logs and small diameter bolts. —NE(1231).

686. In years ahead, it is anticipated that kraft pulp mills in the South will have difficulty harvesting sufficient wood to satisfy their requirements. A machine that harvests and bunches complete trees with taproots intact has been developed. Pulpwood yields per acre are increased by 20 percent and site preparation costs for reforestation are reduced. —SO(1132,1142,1144,1145).

687. The economic removal of hardwoods growing on land better suited for southern pines has been a problem for decades. The development of a shaping-lathe headrig shows how end-chucked hardwood or softwood bolts can be machined into cants for pallets, boards or posts of round or polygonal shape. Wood removed is in the form of flakes or pulp chips.

Cutting energy relates to wood specific gravity and flake thickness. This new equipment represents a major contribution to more efficient wood processing. —SO(1199,1203,-1205,1206).

688. Because of increasing demands for timber and changing utilization technology, chippable residues are now marketable products. There is a need for prediction equations and weight yield tables for estimating chippable residue, bark residue, lumber, and sawdust from various species. A series of reports for various species and products has been prepared. These data will permit timber owners and sawmill operators to estimate yields for standing timber. —SE(1158,1168,1169,1170,1226,1227,1245).

689. A 750-foot long skyline cable system was capable of clearcut logging 3.5 acres, removing tree length logs up to 24 inches d.b.h. in steep mountainous terrain, and, at the same time, reducing surface disturbance from road-building and skidding. The system shows promise for harvesting in the central Appalachians both for clearcutting and selective harvesting. —NE(1155).

690. Nonproductive time, or "down time", is a major cause of reduced profits in hardwood sawmills. Operations at 21 sawmills were observed. The average down time represents 11 percent of total operating time. The biggest part of down time was for repairs, but saw sharpening, log deck jam-ups, log trouble, and talk also reduced productivity. This information may be used by mill managers interested in pinpointing and reducing down time at their sawmills. —NE(1229,1230).

691. A better understanding of wood permeability is essential for the wood drying and treating industries. Air-drying and rewetting increased the saturation moisture content and the permeability of yellow-poplar by eliminating the air bubbles entrapped in the green wood. Hardwoods can be treated more effectively by air-drying the wood first to remove air bubbles. —NC(1163).

692. There is a need to examine why prefreezing improves black walnut drying. Prefreezing was found to increase radial permeability in both heartwood and sapwood of black walnut. Improved permeability probably caused the improvement in black walnut drying; thus, prefreezing might improve permeability—which in turn improves drying in other woods. —NC(1164,1173,1176).

693. The role that extractives play in the hygroscopicity and dimensional stability of wood needs to be investigated. The removal of extractives from black walnut heartwood caused greater shrinkage and a lower fiber saturation point than from the unextracted wood. Certain wood extractives might be added to wood to improve the dimensional stability and drying behavior of wood. —NC(1172).

694. The anatomical structure of northern red oak greatly affects the strength of lumber and the yield of pulp from the species. Wood from trees with a high proportion of fibers, and consequently a low proportion of vessels, is high in both strength and pulp yield. This study shows that average increases of 11 percent in fiber proportions occur when going from site index 25 to 85. Commensurate decreases are shown in the proportion of vessels, rays, and axial parenchyma. Positive relationships between fiber proportions and various mechanical properties are also shown. Of interest to silviculturists and forest managers is the constancy by which the proportion of fibers increases with site index and growth rate. —FPL(1220).

695. Continued consumer demands, particularly for construction lumber and plywood, coupled with a reduced commercial forest land base, make it imperative that consideration

be given to more intensive forest management and wood utilization. Efforts to extend the timber supply include better utilization of forest residues. Opportunities to effectively utilize forest residues and research programs focused on this potential resource are reviewed. —FPL(1248).

696. Correct processing decisions in the manufacture of hardwood or softwood lumber require the machine operator to weigh hundreds or thousands of thousands of alternatives. Since the time is limited and the requirements exceed human capabilities, the decisions are usually less than optimum. Our research is systematically solving this problem by the development of decisionmaking programs and systems for the lumber related industries. Examples include the hardwood lumber cutup program, the hardwood grading program, the Best Opening Face program, and the ultrasonic defectoscope system. Adoption of these systems by industry (now in progress) will greatly relieve the mental workload of machine operators and increase the efficiency of conversion by 10 to 20 percent. —FPL(1188).

697. Presently, lumber cutting decisions are based on what a sawyer sees and his capability to relate this information with product requirements. Inaccuracies and insufficient time result in reduced conversion efficiency. Research has developed an ultrasonic system to sense and locate defects in the work piece, and a computer to make processing decisions, and set and control the saw. Development of a production model and adoption by the industry will improve yields 8 to 12 percent. —FPL(1160).

698. Solutions to the geometrical problem of maximizing lumber yield from logs have eluded the industry for centuries. Precise mathematical modeling of the sawing process promises to solve this question. Such a mathematical model has been developed and in combination with maximization routines, is known as the Best Opening Face (BOF) computer program. Application of this technology as a sawing decision and machine control system is already underway in the industry and promises to increase yield from small logs by at least 10 percent. —FPL(1188,1189,1216,1217).

699. A study with press-lam, a structural product of thick, veneer parallel-laminated wood, has shown that a broad range of creosote retention in press-lam can easily be achieved by variation in treatment schedule, and that preservative penetration is independent of total uptake as compared to solid wood. The improved preservative treatability of press-lam expands the utility of this wood product. —FPL(1246).

700. Constructing particleboards of three layers with poorer material in cores and quality flakes on the surfaces can lead to best use of particle furnish. The dependency of panel stiffness on amounts and type of face and core material is illustrated both analytically and experimentally. The results advance the technology of how processing affects the physical properties of panels to be used in construction. —FPL(1182).

701. Forest residues constitute a vast quantity of largely unused wood raw material. Strong, stable, and durable structural particleboards can be produced from forest residues of Douglas-fir and associated species. Adequate properties can be maintained as long as only small amounts (less than 25 percent in total) of bark, badly decayed wood, or branchwood are included in the raw material mix. —FPL(1214).

702. From one-third to one-half of the face veneer produced from hardwoods grown in the United States buckles during drying and must be redried and flattened in a hot press before use. The experiment showed that buckle could be reduced to one-third that of controls by making the original drying in a hot press equipped with fourdrinier screen as cauls. Best



results with 0.030-inch-thick black walnut were obtained by using a temperature of 230°F. a pressure of 50 pounds per square inch, and a drying time long enough to bring the veneer to about 6 percent moisture content. If the technique is adopted commercially, it should permit the use of lower grade hardwood logs for decorative face veneer. —FPL(1219).

703. The use of high density hardwoods for exterior construction plywood has not been possible because adhesive bonds did not meet the standards. The combining of high and low density hardwoods into one panel makes it possible to use an economical bond and meet the requirements of the standard, PS 1-66. This will permit the substitution of under-utilized eastern hardwoods for use in construction plywood and relieve some of the pressure on the softwood timber supply. —FPL(1198).

704. Research to evaluate supplementary treatments to utility poles in a high decay hazard environment was undertaken. Groundline wood preservative formulations were applied to weathered southern pine pole stubs initially treated with creosote. After 5 years of ground contact, the creosoted control stubs were severely attacked by decay fungi. The groundline treatments were highly effective in preventing decay. —FPL(1165,1184).

705. Performance of finishes on wood exposed outdoors can be vastly improved by treatment of wood surfaces with various inorganic compounds. Simple brush applications of aqueous solutions of the chemicals to wood surfaces can: 1) retard degradation of the surfaces by ultraviolet radiation; 2) enhance effective use of polymer coatings transparent to ultraviolet light; 3) reduce the swelling of wood by water; 4) impart a degree of fungal resistance to the surface and surface coatings; 5) serve to fix the extractives in redwood and red cedar; and 6) lengthen the life of oil-base and latex stains and coatings. Use of the treatment will improve wood as a substrate for finishing. —FPL(1159).

706. Shear blades have generally not been widely accepted as a tool for felling sawtimber due to excessive splitting damage in the butt log adjacent to the sheared face. Thin blades cause less splitting damage; however, they have limited structural stability. Methods to analyze the elastic stability of thin rectangular plates subjected to in-plane compressive loading with varying boundary conditions have been studied. These thin plate solutions can be used to approximate thin shear blade configurations. What is otherwise a very complicated problem has been reduced to a very simple checkout and design procedure which a design engineer can follow to estimate the stability of thin shear blades and to select methods of increasing elastic stability. —NC(1122).

707. Effective treatment of wood depends on the movement of treating liquid through the wood structure. A mathematical model was developed for evaluating moisture uptake, swelling, and moisture distribution during longitudinal penetration of water in once-dried yellow-poplar, black walnut, and red oak. Models of this type can help to predict effectiveness of various wood treatments. —NC(1233,1235).

708. Low-grade yellow-poplar is seldom processed to make high-quality dimension parts. Volume tables are given for low-grade yellow-poplar trees in a 30-year plantation for yield of clear-one-side, flat dimension parts. This information will aid the wood procurer to determine yields from low-grade wood. —NC(1175).

709. There is a need to build recreation structures from low-grade wood. Picnic tables, benches, shelters, cabins, and rustic signs for recreation areas, suitable for heavy use, can be made from No. 2 and No. 3 Common grades of lumber. The

heavy hardwood resists vandalism and wear, and, when properly manufactured and maintained, will give many years of service in recreation structures. —NC(1174).

710. Conventional raw materials for pulp production are in short supply in the Four Corners region of Colorado, Utah, New Mexico and Arizona, limiting prospects for needed economic expansion. Evaluation of an inwoods debarking-chipping system showed that, with improved operating efficiency, cost of inwoods-produced chips could be nearly comparable to that of chips produced at a pulp mill from ponderosa pine and other coniferous roundwood. Substantial benefits were realized in woods cleanup. Quality of chips was excellent. Results have been used by pulp industry in planning expansion. —RM(1151).

711. One-fourth of Montana is forested. The forest's wildlife, recreational opportunities, forage, water, minerals, and timber are important to the economy and environmental quality of the State. Although some problems exist, progress has been made in reducing the conflicts among these uses and in reducing threats to air and water quality. About 11 percent of the State's personal income is directly or indirectly dependent on wood products, and expansion is planned in lumber, plywood, particleboard, and paper production. USDA Forest Service lands provide about half the annual wood harvest, so land use and management programs on National Forest lands have a major effect on supplies. Potential impacts of changes in National Forest harvest levels are estimated. This integrated overview should be of substantial value in long-term planning for the management and use of all forest resources in the State. —INT(1153).

712. Efficient transportation of forest products that is environmentally acceptable requires theoretical analysis of slope stability. The Rankine assumptions were used as a basis for developing equations for calculating active and passive earth pressures within a slope extending to infinity. The analysis considers cohesive and noncohesive soils, the angle of internal friction of the soil, seepage forces caused by a groundwater table parallel to the ground surface, and the plane on which the stresses are found. This research has particular relevance to problems of steep mountainous lands where engineers are studying slope stability and erosion problems. —INT(1137, 1138).

713. Hawaii has a number of useful woods that are not widely used at present. The physical and mechanical properties and appearance of 16 of these woods are described. Such information will help increase the use of these woods. —PSW(1240).

714. Detailed information is needed for quantification of lumber and veneer recovery factors for important commercial western species. A series of reports present these data for old and second growth Douglas-fir, Engelmann spruce, as well as red and white fir. These data are useful to timber managers and forest product manufacturing companies. —PNW(1178,1179,1192,1250,1251).

715. The evaluation of timber access road alternatives is difficult because comparison is related to such values as grade, length, curvature, and volume of excavation. A technique for rapid evaluation of alternatives is presented and should be useful to any engineering office having access to a high speed desk top calculator system with digitizer and plotter facilities. —PNW(1126,1127).

716. Today's rapid advancements in logging technology have created problems in maintaining current logging cost information. New approaches have been developed to reduce the time lag in determining logging costs of evolving timber harvesting systems. —PNW(1150).

717. Forest residues, both living and dead, are now being removed from cutting areas to improve aesthetic appeal and reduce fire and insect hazard. Evidence presented in a new compendium for the Pacific Northwest with contributions from 35 Forest Service authors indicates that a light amount of residue protects new seedlings against environmental extremes and that complete residue removal or destruction will serve as guidelines for land managers in the field of residue management and indicate areas in need of further research. — PNW(633).

#### Wood chemistry and fiber products

718. Kraft chemical pulping yields near 50 percent are a deterrent to accomplishing an extremely high degree of utilization of southern pines. Laboratory techniques provided visual evidence on how fibers could be unwound into more flexible ribbon-like structures. This study will provide information for design of a laboratory machine that will refine pulp for stronger paper at higher yield. —SO(1276).

719. Hardwoods on southern pine sites are being destroyed rather than utilized because of inadequate information on fiber dimensions. Data are presented for stem and branch fiber lengths for 22 hardwood species found on southern pine sites. This publication will aid manufacturers of fiber products in blending species to obtain desired properties. —SO(1275).

720. The corrosion of metal fasteners in wood often causes premature degradation of the wood and a reduced service life of the structure. This report describes the causes and prevention of wood failure due to metal corrosion. An understanding of the causes of wood degradation due to metal corrosion products will lead to better design and longer lasting structures. —FPL(1254).

721. Wood residues could be used as a source of animal feed if suitable ways can be found to break down the wood crystalline structure. Enzymes in ruminants' digestive systems can accommodate some wood untreated, but it was found that delignification of wood by normal wood pulping methods produces material with high rumen digestibility. Steers readily consumed a feeding ration composed of 50-75 percent pulp mill fines. Using wood as a roughage replacement would permit fuller utilization of residues and provide a new feed supply. —FPL(1255).

722. Outside storage of pulpwood chips gives rise to deterioration of the chips from the action of microorganisms and heat. Large amounts of byproducts, such as tall oil and turpentine, and some wood substance are lost. Two promising chemical treatments were evaluated in outside chip piles. One treatment suppressed initial heating and significantly reduced losses of tall oil, turpentine, and wood substance after 2 months storage. Chemical control of chip deterioration will not only conserve wood fiber, but pulp byproduct chemicals as well. —FPL(1289).

723. When green wood chips are stored in large outside chip piles, heating and degradation occurs results in losses of wood fiber. At 65.5°C, in the absence of microorganisms, green southern pine chips are degraded after only 3 months. Subsequent kraft pulping results in reduced pulp yields and pulp strength. Pretreatment of the wood with alkali will prevent loss in pulp yield. Untreated wood chips stored in large outside piles must be treated or protected to prevent or minimize heating and degradation. —FPL(1260).

724. Presently used wood preservatives are effective due to their toxic nature. A clean, permanent, nontoxic preservative making use of the chemical reactivity of wood with alkylene

oxides under mildly alkaline conditions has been developed. Southern yellow pine showed good rot resistance to brown-rot fungi and very good dimensional stabilization when treated to 20-25 percent weight gain. Wood chemically modified in this way, shows promise for above ground application where reduction in water swelling and rot resistance are important. —FPL(1285).

725. To date, there has been no satisfactory method for measuring fiber bonding in paper. A highly useful fiber bonding index derived from web shrinkage energy and sheet density was developed which is free from the limitations of other methods and also offers new insight into the ultimate potential properties of cellulose-based fiber networks. —FPL(1256).

726. There is a shortage of detailed information on fiber recycling studies that simulate papermaking techniques. Conversion of wood into marketable paper products is dependent upon both the initial, or morphological, characteristics of the pulp fiber and on response of this fiber to processing variables. Without question, processing variables, such as beating, will affect sheet strength. However, under conditions of this investigation, sheet strength was influenced most by the original properties of the pulp fiber. —FPL(1268).

727. Conventional manufacturing processes for paper can result in variation of density across the thickness direction. This results in strength and stiffness differences of fiber products due to variations in fiber bonding. This study provides broad scale quantitative assessment of the influence of bonding intensity profiles which can be used as a guide for improving paper and board properties. —FPL(1291).

728. The utility of most fiber products depends on their inherent stiffness. Efficiency in design demands an adequate understanding of the factors which govern paper stiffness. Recent research suggests that there are relatively few factors and quantifies their importance. Factors examined include fiber orientation, density, restraint during drying, thickness, moisture content, and temperature. This information should be of general use to those trying to increase or obtain better control of paper stiffness. —FPL(1288).

729. In the manufacture of corrugated paper on a corrugating machine, fracturing of the corrugations limits how fast the paper can be run. Papermaking factors that affect the runnability of the medium on a corrugator and the strength of the product were established. A mathematical model was developed for predicting runnability from specific paper properties. This information is of immediate benefit to corrugating medium manufacturers in overcoming their present process problems and in providing the consumer with a better container. —FPL(1270).

730. The large volume of fiber in household trash has contributed greatly to the problem of solid waste disposal. This study showed that wood fiber from the paper fraction of household trash can be used in the manufacture of corrugating medium. Starch addition or mixing the waste fiber with pulp presently used in corrugating medium gives the necessary crush resistance. Thus one alternative to the disposal of household trash is by processing into corrugating medium. This dry recovery approach for wastepaper also provides a potential source of fiber to the rapidly growing container industry. —FPL(1273).

731. Wood fiber from urban residues like wastepapers, used pallets, dismantled railroad cars, and diseased elm trees has potential use in wood-base panel products such as medium-density board materials for furniture corestock. Dry-formed, medium density hardboards were made from various combinations of these residues. Most of the properties of the boards



were as good as those required for medium-density, mat-formed particleboard, but they were not as good as three commercial dry-formed, medium-density hardboards. This information will be useful for potential producers and consumers of these materials and to municipalities considering the use of waste for making panel products. —FPL(1274).

732. Pulping with oxygen reduces air pollution and produces 20 percent more pulp than in the kraft process. There are numerous technical problems such as the influence of transition metals, recovery of chemicals after pulping, and influence of wood species on the process. These problems are being attacked with success, and results will have a significant bearing in the development of a single stage oxygen pulping process. —FPL(1271,1272,1278,1279).

733. Softwoods were easily delignified with concentrated potassium hydroxide and sodium hydroxide under mild conditions. Although the cellulose was completely mercerized, the pulps were sufficiently strong but bulky and porous, and handsheet could not be densified to the level typical of kraft pulps. Unmercerized pulps prepared with 5N methanolic potassium hydroxide showed similar compositions and properties except they were more passive to beating. The comparison provided convincing evidence that hemicellulose distribution and cell wall microstructure—and not the mercerization—were critical factors in determining the pulp properties. —FPL(1259).

734. Disposal of fibrous hydrocolloid waste from pulp and papermills constitutes a major problem. *Thermomonospora fusca* is a bacteria that grows well on a variety of low-lignin pulps and papermill fines. Fermentation of such material at 55°C. with this bacterium effects a considerable reduction in their volume and produces a readily harvestable high value protein which can be used for animal or poultry feed. Upon prolonged fermentation, cell autolysis sets in that results in near complete digestion of carbohydrates and further reduction in sludge volume, thus functioning as an efficient disposal scheme. —FPL(1262).

735. Although there have been many publications concerning pine wood extractives, comprehensive studies of these extractives have been hampered by the inavailability of adequate analytical techniques. An analytical scheme has been devised that integrates several newly developed chromatographic procedures to give a detailed and quantitative picture of those pine constituents that are tall oil precursors. Our scheme has been used to obtain benchmark data on the extractives of loblolly pine wood, and on the changes that occur during pulping and storage of the chips. The analytical data permit quantitative evaluation of tall oil naval stores recovery as it relates to processing economics and product quality. —FPL(1295,1296).

736. Paper thickness determined according to conventional or standard methods is not suitable for the calculation of density or stress-strain properties of paper. Surface roughness of paper causes difficulty in the measurement of paper thickness. Inaccurate thickness measurement can result in density values as much as 80 percent off. A new definition and new equipment for measuring thickness that overcomes problems with conventional thickness measuring apparatus is proposed. This work has value to all scientists involved in paper research and is gaining worldwide acceptance. —FPL(1287).

737. If corrugated fiberboard is to be used efficiently in shipping containers to protect contents against thermal exposure or in building applications, a reliable method of calculating thermal properties is necessary. A mathematical model has been developed—based on summation of resistance of in-

dividual components—which provides estimates of steady-state thermal resistance within plus or minus 6 percent. Designers or others involved in protecting contents can utilize corrugated fiberboard more efficiently since total heat transfer resistance can be accurately estimated for any thickness. —FPL(1284).

### Wood engineering

738. Architects and builders know little about changes in moisture that occur behind brick siding or conventional wood siding in exterior insulated wood-frame walls. A study of moisture gradients in these two wall types was made during winter in a mild climate in Athens, Ga. The results show that the wood frames behind brick siding will remain dry during winter even if the interior vapor barrier is broken or omitted because of the air space normally provided between the brick and wall sheathing. The wood-sided wall must contain an interior vapor barrier to stay dry. Properly constructed wood-frame wall systems, using either brick or wood siding, can be expected to remain structurally sound without costly deterioration from dimensional instability, paint peeling, and wood decay, caused by high moisture levels. —SE(1305).

739. Wood has been in a poor competitive position in the guardrail support market owing to a lack of knowledge of how its impact strength characteristics compared with steel posts. Using the Southwest Research Institute's pendulum facility and high-speed movies, it was found that smaller sizes of lower grades of wood are equal or superior to standard steel posts. These results, in combination with earlier work on machine driving (NE-81 and NE-212), are the basis for an industry-Forest Service effort to change State guardrail post specifications. Success in this effort will provide an expanded market for the over-abundant lower grades of wood. —NE(1308).

740. The correlation between the strength and stiffness of lumber is the subject of worldwide investigation in grading research. This paper describes a laboratory instrument developed to detect stiffness variations within pieces of lumber over distances of less than 2 feet. The middle-ordinate method provides a laboratory means of objectively assessing the strength-reducing potential of localized defects in lumber. —FPL(1313).

741. Static bending tests were conducted on small clear specimens from untreated piles salvaged from the Milwaukee River. Strength and stiffness of red pine pile material was substantially lower than published values for the species; white pine and tamarack results showed little or no apparent effects due to the river exposure. Lumber cut from the red pine piles would not be recommended for structural applications using allowable design values for the species. The results of this study challenge traditional positions which have suggested no degradation takes place under immersion. —FPL(1300).

742. There is a need to reevaluate wood properties so that existing reference data will adequately represent the current resource. The mechanical properties and specific gravity of a random sample of black, red, and white spruce and balsam fir were measured on specimens green and at 12 percent moisture content. Average values important in design with lumber and plywood were higher in 23 cases, lower in 6, and unchanged in 11. This data will be submitted by industry for ASTM approval and application to design use in lumber, plywood, and poles. —FPL(1299).

743. Imprecise design procedures for stressed skin panels have resulted in inefficient utilization of materials. Experi-

mental work showed that "shear flow" and "shear lag" mathematical analysis provide an efficient design basis. Use of the analysis leads to better panels with less material. — FPL(1314).

744. Prestressed wood beams have often been advocated in construction, but little is known regarding inherent changes that might result over extended time periods. To evaluate the change in prestressing force due to time-strain characteristics of the wood, matched pairs of prestressed and nonprestressed control beams were loaded for 8 years. The time deflection performance of the matched pairs was consistently similar, and there was no significant loss in the prestressing force. These data indicate that prestressed beams should give adequate performance in structures. — FPL(1301).

745. The wood-frame house is believed to be overbuilt, resulting in inefficient use and waste of the wood resource. Tests conducted during progressive construction stages of a 16- by 24-foot house to determine influence of each component on overall performance showed structural failures were in connections rather than in wood members. Failure loads were far in excess of design loads. This information will guide future research to establish efficient design criteria for wood homes. — FPL(1330).

746. Condensation problems in houses are a major cause of excessive maintenance and heating costs. Research has shown that proper location of vapor barriers and insulation coupled with improved construction techniques will minimize condensation problems. Adoption of the research findings can improve house durability and reduce heating energy requirements. — FPL(1298).

747. The quantity of lumber suitable for engineered glulam timbers could be substantially increased if presently prohibited coarse-grain materials were permitted. Compared to beams with existing permissible combinations, those containing coarse-grain material would likely have only slightly reduced bending strength and stiffness but substantially reduced shear strength. Data have already been used by the glulam industry to establish a specification. Research findings provide a tool to permit more complete and efficient use of the timber resource. — FPL(1324).

748. Glulam timbers, using multiple species in a single assembly, can stretch high grade timber supplies if desired strength and stiffness can be maintained. A theoretical concept permitting combinations of different species within the same beam was developed and evaluated. Research shows that glulam beams made with low strength lodgepole pine inner laminations and high strength Douglas-fir outer laminations will have desired strength properties. Design criteria presented can be used to determine the extent to which lower strength species can be used and the effect on beam properties. The research provides means for more complete and efficient use of the timber resource. — FPL(1325).

749. In addition to softwood plywood, the homeowner has several choices of panel products for new construction or remodeling jobs. Many of these products are made partly or entirely of wood-based material—hardwood plywood, insulation board, hardboard, laminated paperboard, particleboard, and gypsum board. Each product will serve well if used as intended. Information presented will help the homeowner select the materials that best fit his need and pocketbook. — FPL(1331).

750. Noise is a form of pollution which especially effects residential privacy. Single-row-of-wood stud walls are an important alternative for airborne sound insulation for party walls in multifamily dwellings since they use less material, than, for

example, a double-row-of-stud construction. Four different types of design were evaluated under laboratory and field conditions. Two of the designs showed good potential for party wall applications. Results are important to building code groups, builders, and building inspectors because the advantages and limitations of this type of structure are shown. — FPL(1312).

751. Code officials recognize certain inadequacies in defining "noncombustible" materials. A potentially improved method based on "rate of heat release" of a material has been proposed. Information on rate of heat release and methods of reducing it are provided for typical wood-base building materials. Results are important to regulatory officials, researchers, material producers, and others interested in improved and accurate methods of determining combustibility limits and in the proper acceptance of the fire safety of wood products compared to other building materials. — FPL(1303,1304).

752. Because there is extensive loss of life and property damage due to fire, it is necessary to fully understand the fire performance characteristics of wood used in dwellings. This report summarizes information on ignition, resistance to fire penetration, flame spread, smoke development, heat release, fire retardants and fire retardant treated wood. This information is needed by architects, coding authorities, and builders for efficient, safe dwelling construction. — FPL(1310,1311).

753. A knowledge of comparative fire endurance characteristics of structural sandwich panels is necessary if acceptance criteria are to be established for use in single family and other housing construction. Tests conducted on wall panels, loaded to calculated design load and incorporating a variety of face and core materials, provide valuable information on fire endurance characteristics of both sandwich panels and wood-frame wall panels. Performance data on panels incorporating techniques to extend fire resistance are also presented. Feasibility of utilizing sandwich construction is important to code and other regulatory authorities, architects, and builders. — FPL(1306).

### Biological degradation

754. Wood decay involves an extremely complex process that is very important to nutrient recycling in forests as well as to wood preservation and durability throughout the world. Brown-rot fungi, which primarily degrade carbohydrates—such as cellulose—and are reported to produce hydrogen peroxide much more rapidly than white-rot fungi, appear to depolymerize cellulose through a hydrogen peroxide-ferrous iron system. White-rot fungi appear to modify lignin in a process that is largely oxidative. The procedure by which one white-rot fungus, *Polyporus dichrous*, oxygenates specific compounds during lignin biodegradation has been delineated. Biochemists and fungus physiologists will be able to base further research on this information. — SE(469,532,533).

755. The discoloration of asphalt roofing shingles is a problem for homeowners in warm, moist regions of the United States. A blue-green alga was consistently identified as the organism primarily responsible for the discoloration of shingle granules. A variety of fungi, bacteria, and other algae were also isolated from discolored granules, but these were of minor importance although the fungi severely affected the strength of shingles. Recognition of the organisms that cause roof discoloration will permit researchers to develop control procedures. — SO(528).

756. In recent years, an unknown fungus has seriously degraded large softwood chip piles in the United States, Canada, and Sweden. Mycological studies have shown this to



be a new *Phanerochaete* with a *Chrysosporium* imperfect state. Now that is has been identified, researchers can concentrate efforts on developing a technique for controlling the damage caused by this fungus. —FPL(531).

757. Even though termites cause hundreds of millions of dollars worth of damage to wood and wood products each year, their digestive physiology remains poorly understood and controversial. The eastern subterranean termite, the most widely distributed and damaging termite species in North America, proved an efficient degrader of cellulose and hemicellulose and a poor degrader of lignin. Despite this species' reported ability to fix atmospheric nitrogen, the total nitrogen in the termite-wood test system decreased during the 4-week test period. A better understanding of termite nutrition and digestive physiology should increase the possibility of achieving practical termite control through a highly selective description or blocking of termite feeding. —FPL(431).

#### Prevention and control of wood-destroying organisms

758. Fungi and insects cause considerable damage to wood throughout the country. This damage is especially important when it involves high-value or critical items such as posts, poles, or supporting components of buildings. Techniques have been developed for recognizing and preventing or minimizing this damage. Pest control operators, architects, builders, and others will be able to contribute toward reducing wood loss by implementing these techniques. —SO(529,530).

759. Although wood of most species is severely damaged by termites, certain woods seem relatively immune from termite attack. Components extracted from Port-Orford cedar, eastern redcedar, western redcedar, baldcypress, and redwood contained substances detrimental to termite attack and survival. Once these termite detrimental compounds are isolated and identified, either they or closely related compounds may possibly be used to protect susceptible wood from termite damage. —SO(429).

760. Wood from Central America is a potentially valuable addition to our native wood supply, yet we know very little about many of the woods' resistance to subterranean termites. Of 97 wood species, 14 permitted no survival by either of the two test organisms—one native and one introduced termite species. Thirty-one additional wood species permitted no survival of the native species and only low survival of the introduced species. These groups of woods were considered resistant. Identifying the compounds responsible for the resistance of Central American woods to subterranean termites may lead to the development of selective termiticides or non-toxic repellents or feeding deterrents. —SO(428).

761. Although the wood-destroying beetle, *Xyletinus pelatus* is probably the most damaging beetle of seasoned wood in the southeastern United States, the factors influencing its choice of wood species for egg-laying are unknown. Contrary to their typical habit of damaging softwood timbers in buildings, they preferred a hardwood—yellow-poplar—for egg-laying. The basis for this selection is unknown. Additionally, the beetles preferred rough surfaces for egg-laying. This beetle is obviously capable of damaging many woods used in homes, and its abundance in softwoods probably reflects building practices more than beetle preferences. —SO(433).

762. Preliminary experiments with toxic baits to control subterranean termites have given favorable results in southern Canada; however, we need to know how effective this technique would be in the South where termites are much more abundant. Baits were placed on a grid at 5 foot intervals and each bait used a very small amount of a toxic chemical.

Termite attacks were effectively suppressed for 3 years with a single bait treatment. The toxic bait treatment appears sufficiently promising to expand research by testing its efficacy against a variety of termite species in different climates under a variety of operational conditions. —SO(430).

763. Improper log storage prior to sawing at mills results in serious losses of wood quality and quantity. These losses can be avoided with properly constructed and maintained storage facilities that minimize conditions favoring insects, fungi, and stain damage to logs before they are sawn in the mill. A checklist provides standards to be met by modern log yards to eliminate damage during the storage period. Proper storage will increase quantity and quality of lumber produced from hardwood logs. —SO(432).

#### Marketing Under-used Species and Residues

764. Recent enactment of anti-pollution regulations promoted the development of new processes and markets for utilizing bark residues. Bark products have been developed for use in agriculture, industry, and construction. Markets for mulches and soil conditioners have been established in the horticultural trades and garden stores. The 1972 market for horticultural bark products was estimated at \$30-40 million. Research and development efforts in processing, handling, and application of bark have provided timber processors with alternative use opportunities in most sections of the country. —NE(1062,1063,1064,1065,1066,1070,1071).

765. Low density wood species have long been considered inferior for production of durable pallets. Research has determined that species such as aspen can be used effectively provided the lumber is properly used and the pallets are adequately designed. Aspen pallets can be at least 1 1/3 times as stiff and 1 1/5 times as rigid as oak pallets of the same basic design. Use of low density species can greatly increase supplies of raw material suitable for pallets. —NE(1067,1068,1069).

#### Supply, Demand, and Price Analysis

766. How much should be invested in forestry today and in the near future to provide the timber that will be needed at the end of this century and beyond? This study attempts to answer the question for the State of Georgia. It provides a systematic means of assessing the long-run economic outlook for investments in Georgia forestry. —SE(1084).

767. North American production and consumption of wood-based panels increased rapidly over the past decade, and the industry continues in a state of rapid change. New products and processes are continually being developed. Large, new production plants are being built. This suggests strong inter-product competition for raw materials and for markets in the years ahead. This view of current and prospective trends in the wood-based panel industry is of interest to all those concerned with production and consumption of wood raw materials and finished products. —WO(1086).

768. Information on the amount of wood products consumed in construction of nonresidential buildings is needed for accurate assessment of current and prospective demand for timber. The volume of lumber and panel products used in different types and structural classes of buildings was measured. Wood use factors were developed. The volumes of different wood products used, by building type and building component, are presented for use of processors, marketers, and others interested in the size and nature of this important market and

its effect on the current and prospective demand for timber products. EWO(1087,1088).

769. There is widespread interest in, and need for information on the demand and price situation for forest products. Current timber industry statistics on production, prices, trade and related items have been brought together and analyzed for ready reference of producers, marketers, consumers, consultants and others interested in up-to-date information about the forest products situation and trends. The time series data on production, imports, exports and consumption form the basis for assessment of current and prospective demand for timber. —WO(1074,1075,1076,1085).

770. The demand for housing is a major determinant of the prospective demand for lumber, plywood, and other forest products. Declining population growth and major shifts in the age structure of the population in coming decades will profoundly affect both the number and type of dwelling units required in the second half of the 1970's and beyond. This information is vitally important to all timber growers and processors. —NC(1081,1082).

771. Despite the high lumber and plywood prices associated with housing booms, wood products have not been a major cause of increased housing costs. Analysis of housing input prices, home ownership costs, and house prices in the postwar period show that rising land costs, taxes, wage rates, and interest rates contribute to rising housing costs. The outlook suggests that factors other than building material supplies will control future housing production. —SO(1077).

### Improved Marketing Systems

772. Extreme variation in sizes of loads hauled on Appalachian logging trucks prevents optimization of hauling costs. Measurement of 125 loads from seven cutting sites showed differences of 10,000 pounds and 1,000 board feet per load even for the same truck, driver, and cutting site. Four out of five trucks were loaded below legal weight limits. Hauling costs can be reduced at least \$5.00 per MBF by increasing average load size through use of higher stakes, presorting and proper placement of logs on the load, and double tiering short logs to use more of the available cargo space. —NE(1115).

773. Conventional grade-sawing of small, low-grade hardwood logs is generally unprofitable for mills without resaw equipment. Live-sawing resulted in reduction of break-even log diameter from 12 to about 9 inches. Use of the live-sawing method will permit hardwood sawmills to saw more low-grade logs and help extend the hardwood timber resource. —NE(1099).

774. A national pallet exchange program could reduce materials handling and distribution costs by many millions of dollars. Research indicates that performance of warehouse and

exchange pallets depends on quality of pallet shook, deckboard-stringer fasteners and fastening system, construction design specifications, and conditions of use. Prudent application of such research and development results can reduce initial pallet cost, increase pallet life, and decrease overall pallet use costs. —NE(1091,1114,1116,1117).

775. High labor turnover in wood products industries results in wasted manpower, needless production losses, and higher costs to the industry and its consumers. Quit rates in wood industries were found to increase during expansions in economic activity and to fall during recessions. Changes in quit rates over time can be explained by variations in unemployment rate, composition of the labor force, and earnings of wood industry workers relative to other workers in the economy. This study helps to explain present levels of wood industry labor mobility and identifies factors that are likely to determine future changes. —NE(1118).

776. Producers of pure maple syrup have little knowledge of consumers' preferences and purchase habits. Users of maple syrup in syrup-producing regions differ from consumers in other parts of the country. A survey analyzed differences in user attitudes, preferences, and purchase and use patterns. Results are being used to guide the United States Maple Institute in developing a national promotion program for maple syrup. Other research has shown how to increase efficiency and lower costs in production and distribution of maple syrup so as to improve its competitive position with lower-priced maple blends. —NE(1089,1097,1108,1109).

777. Purchasing pulpwood by weight is becoming established practice in the Lake States, but accurate weight-volume conversion factors for Minnesota pulpwood have been lacking. Seasonal weight-volume relationships were determined for aspen and black spruce and are now being used by buyers and sellers to establish more equitable pulpwood weights for sale transactions. —NC(1102).

778. Raw materials for pulp production are in short supply in the Southwest, limiting prospects for expansion. Evaluation of inwoods pulp chip production showed that cost of woods-produced chips could be comparable to chips produced at mill from ponderosa pine and other coniferous roundwood. Substantial benefits accrued from woods cleanup. Chip quality was excellent. Results have been used by the pulp industry in planning expansion. —RM(1107).

779. Timber managers and operators often can't decide what utilization alternatives produce highest values from a given timber base. A unique multiproduct inventory system coupled with a computer program (MULTI), calculates timber volume in a number of product classes. Any set of product specifications may be stated, and value priorities may be set to maximize volume of highest value products. Results will be used by local industry and forest managers to determine best product mix. —RM(1119).





## FOREST ENVIRONMENT RESEARCH

### Watershed Management Research

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# FOREST ECONOMICS AND MARKETING RESEARCH

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613 (51, 759, 761, 764, 765, 772, 774,  
858, 860, 861, 876, 979, 1013, 1156,  
1187, 1189, 1209, 1225)  
yield tables 608 (869, 1169, 1226, 1250)  
youth camps (300)

## Z

ziram 293 (525)  
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## 2

2,4-D 33, 36 (192, 200, 201, 412)  
2,4,5-T 10 (22, 201)

## 3

3P sampling 396, 616 (870, 1022, 1023)

## 4

4-alkoxyl group oxygenation (533)













SD11  
58  
2

SEND TO STACKS

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# FOREST SERVICE RESEARCH ACCOMPLISHMENTS 1976

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11 27 1976  
U.S. DEPARTMENT OF AGRICULTURE  
FOREST SERVICE

## **ACKNOWLEDGEMENT**

**The cooperation and assistance of the Forest Service research personnel is hereby gratefully acknowledged. This publication was partly produced through the Oak Ridge Computerized Hierarchical Information System (ORCHIS) at the Oak Ridge National Laboratory, Oak Ridge, TN.**

UNITED STATES DEPARTMENT OF AGRICULTURE  
FOREST SERVICE

P. O. Box 2417  
Washington, D.C. 20013

1380 (4000)



Honorable M. Rupert Cutler  
Assistant Secretary  
U.S. Department of Agriculture  
Washington, D.C. 20250

Dear Dr. Cutler:

I am pleased to send you the report on Forest Service Research Accomplishments for 1976.

This report summarizes Forest Service research achievements and lists research publications. It reflects the emphasis of a research program directed at solving the multifaceted problems of managing our Nation's renewable natural resources.

New knowledge and technology reported here will be useful to other scientists and to practitioners in Federal, State, and private employment. The Forest Service is strengthening its efforts to assure that this information is quickly transferred to and utilized by those who need it.

Sincerely,

JOHN R. MCGUIRE  
Chief





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**FOLLOW THE LABEL**

U.S. DEPARTMENT OF AGRICULTURE

NOTICE: The identification and description of commercial products in this publication are solely for information purposes. Endorsement of any commercial product is not intended and must not be inferred. Readers are cautioned to handle all pesticides, herbicides, and fungicides mentioned in this publication strictly in accordance with manufacturer's labels. These chemicals are harmful to people, farm animals, wildlife, and fish, and can contaminate water supplies.

## FOREWORD

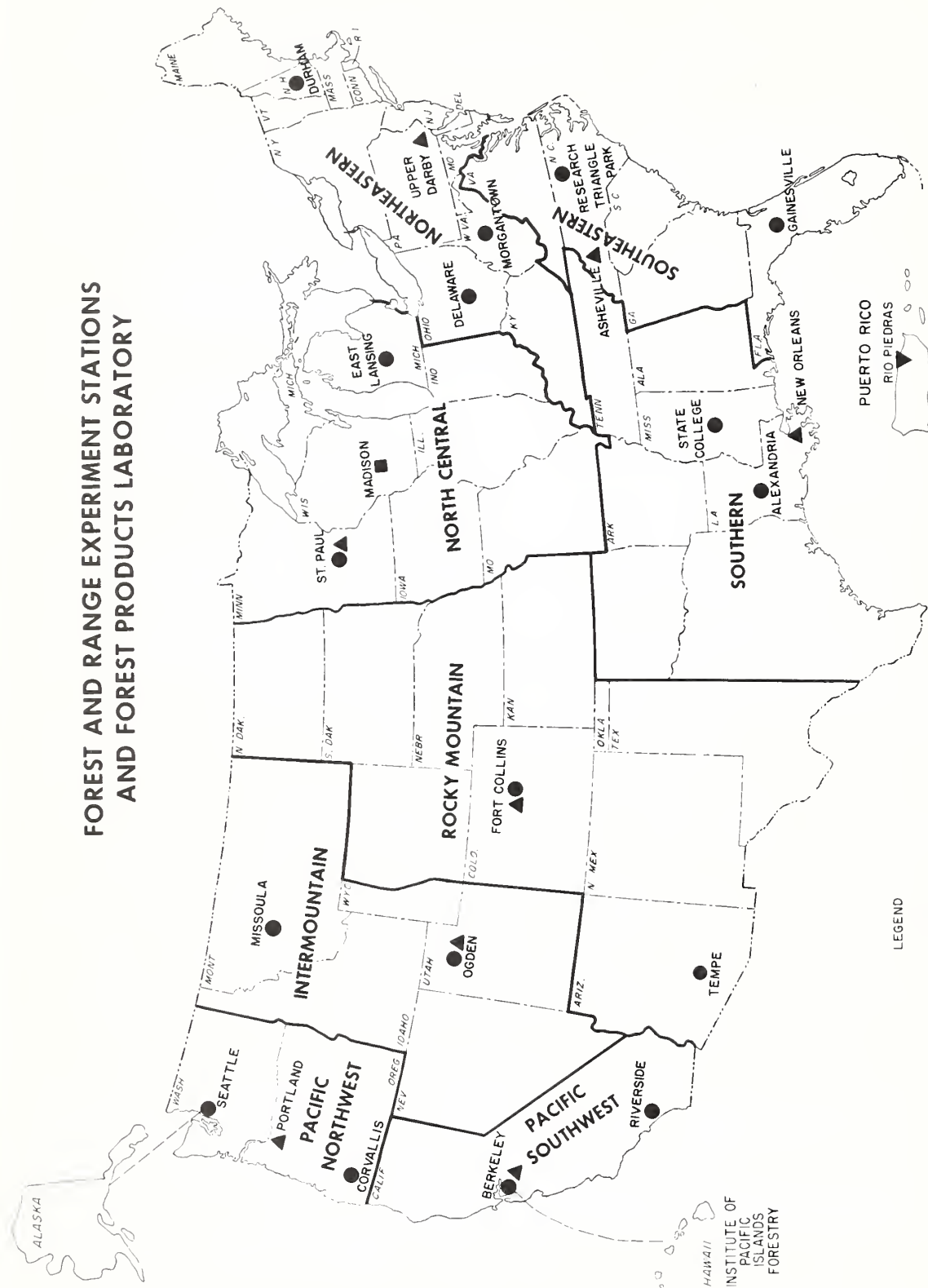
Forest Service research plans are coordinated through the Assistant Secretary for Conservation, Research, and Education with research in other USDA agencies, as well as that conducted under the Hatch Act at land grant institutions, and under the McIntire-Stennis Act at schools of forestry.

Development and coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies are accomplished through the Regional and National Agricultural Research Planning Program directed by the Agricultural Research Policy Advisory Committee and the National Planning Committee.

Coordination is also maintained through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements providing for joint development and support of the research by the cooperators.

This report is arranged by research subject areas as a convenience to the reader. Each accomplishment is summarized in a single, short paragraph. Numbers in parentheses following the paragraph indicate relevant documents in the Publications List. Following each publication citation is an abbreviation indicating the Forest Service research unit best able to supply detailed information and copies of the publication. Abbreviations and addresses of the research units are given on the following page.

# FOREST AND RANGE EXPERIMENT STATIONS AND FOREST PRODUCTS LABORATORY



## LEGEND

- ▲ STATION HEADQUARTERS
- ASSISTANT STATION DIRECTOR LOCATION
- FOREST PRODUCTS LABORATORY
- ▼ INSTITUTE OF TROPICAL FORESTRY

INSTITUTE OF TROPICAL FORESTRY  
PUERTO RICO AND U.S. VIRGIN ISLANDS



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Portland, Oregon 97208

### PSW

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Pacific Southwest Forest and Range Experiment Station  
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### INT

Director  
Intermountain Forest and Range Experiment Station  
507 25th Street  
Ogden, Utah 84401

### RM

Director  
Rocky Mountain Forest and Range Experiment Station  
240 West Prospect Street  
Fort Collins, Colorado 80521

### NC

Director  
North Central Forest Experiment Station  
Folwell Avenue  
St. Paul, Minnesota 55101

### NE

Director  
Northeastern Forest Experiment Station  
6816 Market Street  
Upper Darby, Pennsylvania 19082

### SE

Director  
Southeastern Forest Experiment Station  
Post Office Building, P. O. Box 2570  
Asheville, North Carolina 28802

### SO

Director  
Southern Forest Experiment Station  
T-10210 Federal Building  
701 Loyola Avenue  
New Orleans, Louisiana 70113

### FPL

Director  
Forest Products Laboratory  
North Walnut Street  
P. O. Box 5130  
Madison, Wisconsin 53705

### ITF

Director  
Institute of Tropical Forestry  
University of Puerto Rico  
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P. O. Box AQ  
Rio Piedras, Puerto Rico 00928

### WO

Deputy Chief for Research  
Forest Service  
U.S. Department of Agriculture  
Washington, D.C. 20250

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# IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS

## REDUCING POLLUTION

### Controlling soil erosion

1. Erosion following wildfire on either unlogged or cutover areas is an important concern to land managers especially in areas of highly erodible soils such as the Idaho Batholith. A variety of post-wildfire measurements of erosion, vegetation responses, and soil and water repellancy was conducted on a clear-cut and an undisturbed watershed. Fuel loading was much higher on the clearcut watershed. This resulted in a greater burn intensity and considerable erosion on the clearcut drainage. The undisturbed watershed exhibited only slight erosion due to protection offered by dead, standing trees, unburned litter, and more rapid vegetation regrowth. This information reinforces the need for proper slash disposal on logged areas. (13)

2. The role of sediment storage in channels, previously overlooked, was studied in channels draining seven small undisturbed forested watersheds in central Idaho. The annual change in sediment stored was measured. Additional data were collected to evaluate the influence of natural obstructions on sediment storage. Extremely large volumes of sediment were trapped behind obstructions in two sample years; only about 10 percent of the stored sediment appeared as annual sediment yield. A continuity equation was used to estimate the annual watershed erosion. This study illustrates the need to include channel sediment storage as a subsystem in predictive modeling of sediment. (14)

3. Resource planners need to evaluate the impact of possible reduced water quality from areas subject to forestry activities. The hydrologic potentials of sub-units of a watershed for producing water, floods, and sediment, were evaluated with models that characterize potential impacts of proposed land uses. The techniques illustrated suggest ways for the planners to obtain quantitative evaluations of sedimentation and water quality hazards in land units being considered for specific uses. (1,2,3,4,5)

4. Water movement in coarse textured soils on burned chaparral areas in southern California is impeded by hydrophobic substances coating the mineral soil particles. Lower infiltration rates in these water repellent soils are important factors when evaluating runoff and erosion from brushland areas. The relationships presented provide a fundamental basis for understanding how water moves through these soils and show, contrary to common experiences with soils, that infiltration is slowest in a dry soil and increases as soil water increases. Slower infiltration resulting from repellency may not be desirable for erosion control purposes. However, water repellency also decreases evaporation which may provide a water saving mechanism useful for plants living in the arid southwest environment. (6)

5. Prescribed burning is being considered as a possible tool for widespread fuel modification on chaparral areas in southern California. The impact of fire on plant nutrients is an important consideration when initiating a large scale burning program. A

recent study showed that less than 6 percent of the total nutrients found in the upper soil layers was lost immediately after a fire. Results of this experiment should be useful for estimating nutrient losses from chaparral brushland areas, having slopes of 50 percent or less, after a prescribed burn in the summer. (65)

6. Forest management can significantly affect slope stability in the western Cascades. Studies show that the present landscape of the H. J. Andrews Experimental Forest was formed during the past 4 million years by alluvial, glacial, and mass movement processes. The occurrence of both deep-seated and shallow mass movements is controlled by bedrock geology. Identification of this close link between bedrock geology and mass movement is useful in forest management decisions such as road planning on similar lands in the western Cascades. (16)

7. Bare roadside slopes are especially vulnerable to erosion during the first few months after construction. Despite successful germination and early establishment, legumes are unable to compete with grasses and largely disappear from most roadside stands after 1 year. In western Oregon, grass-legume seed, fertilizer, and straw mulch applied to road backslopes, for the most part, successfully halted erosion. Infertile subsoils required refertilization. The mulch, fertilizer, and grass-legume mixtures identified in this study provide a good tool for stabilizing road cut and fill slopes. (8)

8. Intensive forestry cultural practices in the Gulf Coastal Plain must be evaluated in terms of their potential impact on soils and on water quality. Results from severely eroded watersheds now stabilized with pine plantations show an average annual sediment content of 58mg/l in stormflow from undisturbed forest conditions, with concentrations sometimes exceeding 140mg/l. A maximum of 80mg/l of suspended solids is suggested by EPA. Pollution regulations must be based on sound data. A research approach to obtain these data is outlined. (11)

9. The hydrologic impact of skidding tree length logs up slopes of erosive Gulf Coastal Plain soils was evaluated over a 2-year period. Stormflow from the skid trails averaged 28.4 cm, while flow from undisturbed areas averaged only 2.8 cm. Soil loss averaged 14.8 kg. per trail in the first year but diminished rapidly as the bared soil became covered by herbaceous vegetation. Results will help land managers decide on measures needed to reduce sediment production. (7)

10. Gathering erosion data can be time consuming. A fast and efficient way of collecting erosion data has been developed. Research scientists at Bera, Ky. have developed a method whereby they photograph a micro-topographic profile gage to produce charts that can be analyzed with a chart reader. Erosion measurements that would normally take days in the field and weeks in the office are now reduced to a matter of hours. (45)

11. Knowledge of land form evolution from youthful to old-age stages is needed to develop criteria for understanding gully

development and control. In a western study, youthful and early mature stages of gully development were defined. Comparison of hydraulic geometry of gullies with that of rivers suggests that mature stages should be characterized by dynamic equilibrium. Gully stages expressed in terms of erosion rates and sediment yields would be useful to watershed managers. (9)

12. Vegetative cover that perpetuates itself without further maintenance is needed to rehabilitate disturbed sites. Two planting sites with narrow submerged burlap strips showed 14 times less soil loss than control sites without burlap. Plant cover is established before disintegration of the burlap, in about 5 years. This method provides land managers with a proven technique for bank stabilization and erosion control. (10)

13. Information on erosion and sedimentation rates, essential for proper land management, is not available for sagebrush lands. Seasonal trends in sediment transport were described for two Wyoming watersheds having perennial waterflow at 2380m elevation. With peak sediment concentration of 300 ppm during maximum flow, and average summer levels of 20 ppm, sediment yields compared favorably with those from subalpine forests. The results can aid in evaluating effects of various management practices on sediment yields. (15)

#### Chemicals in the forest environment

14. Stream contamination can result from application of herbicides to forest land. A peak concentration of 0.037 mg/l dicamba occurred in water 1.3 kilometers downstream from a 67 hectare treated portion of a 244 hectare watershed in western Oregon. No residues were detected more than 37.5 hours after application. A 25 percent reduction of dicamba in streamwater occurred between sampling stations located 3.1 kilometers apart. Residue levels detected pose no acute toxic hazard to aquatic organisms or to downstream water users. Knowledge of the behavior of chemicals is important to the prevention of environmental contamination. (23)

15. Nitrogen fertilization, an important practice in part of the Douglas-fir region, has a potential for stream contamination. Application of nitrogen fertilizers was monitored in the Douglas-fir region between 1968 and 1974. Direct application of urea to drainage channels was usually responsible for the highest nitrogen concentrations. Maximum concentrations of nitrogen in the streams after fertilization have not exceeded levels acceptable for public water supplies. (21)

16. Urea fertilization of Douglas-fir stands in western Washington can reduce water quality. Applied fertilizer reached surface streams as urea, ammonia, and nitrate-nitrogen but maximum concentrations were well below limits established for public water supplies. The highest level of nitrate-nitrogen was 0.1 mg/kg. The amounts of nitrogen in the forest streams should have little impact on eutrophication. (22)

17. A root pathogen, *Phellinus weirii* (Murr.) Gilb., kills many immature Douglas-fir in the Pacific Northwest. Laboratory cultures were grown with different carbon and nitrogen sources and vitamins to see if the fungus prefers certain nutrients. Significant differences in mycelia weights resulted from different C and N sources. All but one vitamin produced no effect. The study suggests ways to improve media used for studies of *P. weirii* and aids in understanding the role of the fungus in C and N cycling. (19)

18. A greater understanding of pesticide effects on forest ecosystems is needed. A computer model was developed to simulate the movement of 2, 4, 5-T and picloram in an Oregon forest and southern California chaparral. Seasonal changes, the action of chemicals on natural processes, and physical environmental effects were considered. In addition to identifying research needs on the two herbicides, the model provides a means to make accurate predictions of pesticide effects and to specify correct application parameters. (24)

19. Cacodylic acid is widely used as a silvicide and herbicide but might be toxic to cattle. Five cattle were subjected to 10 mg/kg/day for 3 weeks, followed by 20 mg/kg/day for 3 more weeks. Post-mortem examinations indicated damage to the intestines, liver, and kidney. Kidney tube damage and accumulation of arsenic in hair were extensive. The results may be useful in diagnosis of cacodylic acid poisoning. (18)

20. Forest fertilization with nitrogen may affect stream water quality. To shed light on this problem, four streams in southeast Alaska were studied, two in urea fertilized drainage and two in unfertilized drainage. N levels increased for up to 1 year in the treated streams but remained safe for aquatic life and public use. No changes were noted in bottom aquatic organisms. If proper care is used, forest fertilization is an environmentally sound practice. (20)

21. Conversion of chaparral to grass has been shown effective in increasing water yield. Spot treatments and broadcast applications of soil-applied karbutylate show promise as a chemical control for chaparral. Water samples collected at the stream gaging station showed varying concentrations of karbutylate depending on the length of time since treatment. Karbutylate was not detected in samples taken about a half mile downstream from the treated watershed. In view of the low levels of residues resulting from a 20 lb/acre application and because of the low toxicity rating of karbutylate, there is reasonable hope that karbutylate will be an environmentally safe chemical for controlling chaparral. (17)

22. Of major concern when an herbicide is used is how long it persists in the environment. Recent research in central Louisiana indicates that both picloram and dicamba remain in sprayed foliage until the leaves fall. Picloram was more persistent and was influenced less by soil type and litter cover than dicamba. Dicamba was less effective and less persistent on well-drained, Ruston sandy loam with litter cover than on Beauregard clay loam. These results define some factors to be considered in assessing the persistence of picloram and dicamba when applied as a foliar spray and will be of value to other researchers seeking effective, environmentally safe herbicides. (842)

#### Air Pollution

23. The effects of open burning on ambient air quality are not generally known. About 1 million acres of agricultural and forestry land are burned by prescription in Georgia each year. Since atmospheric conditions ideal for open burning are also ideal for smoke dispersion, overall concentrations of most particulates in rural areas are higher at other times of the year than when most open burning is occurring. Furthermore, a general smoke dispersion model has been developed as a way to incorporate air quality criteria into prescribed burning decisions. It appears that open burning is causing no greater area-wide air pollution problem in Georgia than the sum of other activities at other times.



Managers applying these results can be relatively sure that smoke from their prescribed fires will not become a public hazard. (682,673,686)

24. Particulate emissions are the most objectionable atmospheric contaminant from forest burning, and little is known about particulate sizes. Electron photomicroscopy of particulate emissions from laboratory burning of logging residues confirmed the existence of two basic particle structures—a smooth, spherical, submicron particulate suspected to be condensed tars and a group, polydisperse in size, that did not tend to agglomerate. This basic type of information is needed for the development of smoke management strategies. (720)

25. Assessment of recreational development on air quality is not being done with any specific or approved procedure by the Forest Service. A procedure has been developed which includes use of models coupled with onsite data collection and other information resources. Such a general procedure requires more elaboration, but it eventually should form the basis for Forest Service procedures in air quality analysis. (733)

26. Air pollution decreases the growth of ponderosa pine on the San Bernardino National Forest. Annual stem growth data are needed for management planning in those stands with chronic injury caused by oxidant air pollutants. Average radial growth, based on a 30-year period, was significantly higher in nonpolluted areas than in polluted areas of the forest. This information can be used by land managers to develop stand management prescriptions. (667)

27. Lack of consolidated background material prevents efficient investigation of present and potential effects of air pollutants on forests. A broad literature review has been prepared which contains the histories of important incidents of damage to forests in the United States and Canada caused by the most serious pollutants—sulfur dioxide, fluoride, and photochemical oxidants. This review will be of value to those engaged in research planning. (668)

28. Air pollution injury of urban forests is of intensifying biological and economical importance in the eastern United States. The effects of air pollution on forest tree species have been summarized, and suggestions on how to reduce air pollution impact have been outlined. Managers of urban tracts should benefit from this information. (660)

29. Trees can reduce levels of atmospheric pollutants such as sulfur dioxide, but information on the capacity and efficiency of trees as air cleaning agents is limited. Seedlings of several hardwood species were fumigated with sulfur dioxide. This chemical initially accumulated in leaves and upper stems; but after 8 days, measurable amounts were transferred to roots. Identification of absorption sites and translocation paths of air pollutants in seedlings may aid in elucidating scavenger roles of mature trees. (664,665)

30. There are serious gaps in the knowledge of the relation between short- and long-term exposure of trees to air pollutants. Fumigation of hybrid poplar clones in controlled-environment chambers with either 5 ppm sulfur dioxide for 1-1/2, 3, or 6 hours or with 0.25 ppm sulfur dioxide for 6 weeks produced similar plant responses (growth; foliar injury) to the two concentrations. Determination of the sensitivity of plants by short exposures to a high level of pollutant may facilitate selection of genetically tolerant stock. (662)

31. The effect of air pollutants on all stages of growth and development of trees must be determined before the total consequences of air pollution on trees can be assessed. In continuing investigations of the effects of ozone on tree seedlings, it was found that growth of white birch seedlings was reduced by fumigation with 25 ppm ozone for 110 days. Growth was not reduced on fumigated seedlings of yellow birch, eastern cottonwood, bigtooth aspen, Japanese larch, or white spruce. (666)

32. Trees may condition contaminated air and reduce daily pollution levels. Approaches toward minimizing toxic concentrations in urban areas have been outlined. Research priority must be given to delineating potentials of trees for cleansing urban environments. (661)

33. There is increasing concern about acid precipitation because of its potential for long-term injurious effects on crop production. A recent symposium on this topic with speakers from several countries endeavored to determine the state of knowledge of the acidity phenomenon. Brief reports by these participants contain information valuable in determining research priorities. (663)

### Recycling wastes—sewage effluent, sludge, and residues

34. Forests may offer advantages over farm crops for recycling sewage effluent, but few forest-soil systems have been tested. In southern Michigan, tests over three growing seasons on pine plantations and a hardwood site produced adequately renovated water below the root zone from effluent applied at 50mm/week, 3mm/hr maximum rates. Boron, N, and K levels increased in the red pine foliage along with increased growth. Boron toxicity may limit use of red pine sites. The tests indicate maximization of tree growth from sewage effluent should be subordinated to maintaining a viable ecosystem. (29)

35. There is an increasing need for environmentally safe methods of sewage sludge disposal. Energy development is increasing the areas of strip-mined lands needing reclamation. Use of sludge on strip mined lands offers a solution to both problems. Studies in southern Illinois show that highly acid spoils can be revegetated and leaching of acids and heavy metals reduced by sludge treatments. Heavy sludge applications may cause excess nitrate nitrogen leaching, however. The studies have provided guidelines for a pilot project on the Shawnee National Forest. (25)

36. Winter irrigation of forests with sewage effluent would aid municipalities but requires adequate soil infiltration. Tests on sand soil plots forested with jack pine and scrub oak showed that effluent did infiltrate in most plots throughout the winter, and effluent distribution on the surface and within the soil mass was limited. However, nitrogen renovation was low as compared to the growing season. It can be concluded that winter irrigation of forest soils should be limited to areas where maintaining ground-water quality is not critical. (26)

37. Cities are turning to forest irrigation systems to dispose of sewage effluent, often without a thorough knowledge of environmental effects. Studies of soil chemistry after 9 years of effluent irrigation showed only nominal changes in potassium, sodium, manganese, exchangeable hydrogen, ozone, and phosphorus. No detrimental effects on the soil could be determined. The results can be used in planning effluent disposal facilities and forest irrigation. (28)



38. Introducing large amounts of phosphorus into forest soils through fertilization or sewage disposal can trigger phosphorus movement through the soil, eventually causing algal bloom and reduced water quality in streams and lakes. A method has now been found for determining the amount of phosphorus a soil can absorb safely. In a California test, contrasting forest soils showed more than fivefold differences in their capacities to retain phosphorus. The method can be used to identify soils where fertilization or sewage waste disposal treatments may damage downstream water quality. (27)

39. Conversion of farm livestock yards into confinement feedlots with many animals can increase the concentration of wastes in the feedlot runoff and kill trees in windbreaks that surround and protect these feedlots. Studies in Nebraska have shown that after 2 to 3 years of heavy feedlot use, surface runoff from feedlots into the adjacent windbreaks increased the soil pH and conductivity, altered the exchangeable cation status, added toxic organic substances and heavy metal cations, and produced biodegradable organics that reduced free oxygen in the soil. Combinations of these factors likely killed the trees on the windbreaks. Since overland flow, rather than lateral movement through the soil, transported the toxic substances into the windbreak, grading to divert the flow or selecting upslope locations for new plantings will help alleviate this problem. (155)

## IMPROVING WILDLIFE, RANGE, AND FISHERIES HABITAT

### Characteristics and values of plants for food and cover

40. What are the long-term effects of repeated winter, spring, and summer fires on growth and survival of longleaf pines and the yield and composition of understory vegetation? On a site near Alexandria, Louisiana, 12 years of biennial May fires resulted in significantly greater height and diameter growth of pines. July fires eliminated most woody stems, although several pines survived. Herbage yield differences between burning treatments were not significant. Managers of longleaf forest lands, particularly those on which grazing or other uses are derived, should find May burning useful for improvement of longleaf pine growth. (177)

41. Native forages are deficient in quality during the winter in the southern forests. To remedy these deficiencies for wildlife and livestock, several introduced forages were studied for the Ozark and Coastal Plain forests. Cool-season introduced grasses improved forage quality, especially during winter. These perennial grasses produced more forage than native grasses under pine canopies. Specifically, elbon rye provided an abundant and palatable forage during winter, when native forages were not as plentiful, as nutritious, or as digestible. These results provide the manager with an opportunity for increasing deer and livestock capacity of Ozark and Coastal Plain forests. (208,216)

42. An inadequate source of high quality forage severely restricts the over-winter population of white-tailed deer in the South. The problem can largely be overcome by planting and fertilizing improved plants such as Japanese honeysuckle. In northern Arkansas, nitrogen fertilizer substantially increased the vegetation yields. Both nitrogen and  $P_2O_5$  increased the crude protein contents of honeysuckle leaves. Ash, calcium, and phosphorus contents of leaves declined as levels of nitrogen were increased, but calcium, phosphorus, and magnesium all re-

sponded positively to  $P_2O_5$ . These results indicate that forest land managers can increase the deer carrying capacity of southern forests by intensive culture of honeysuckle on small selected areas. (214)

43. Range grass production varies greatly from year to year in the Southwest. For managers to maintain both grass and livestock production at optimum levels, the numbers of grazing animals must be commensurate with available forage. Monthly rainfall records at the Santa Rita Experimental Range were used to accurately estimate forage production. This technique can give forage predictions at much lower cost than field surveys. (162)

44. Semidesert rangelands are used for livestock raising, wildlife production, and recreation. All of these uses require maintenance of vegetation for food and cover. Research during the past 10 years found grass yield increased 52 percent following control of mesquite on semidesert ranges. This increased grass production repays control cost in about 6 years, and the increases are expected to continue 15-20 years. However, the number of cattle permitted to graze these improved ranges must be carefully regulated to avoid overgrazing and permanent damage to the range—especially during dry years. These results can be used in developing management guidelines for semidesert ranges. (164)

45. Development of effective grazing systems requires not only an understanding of the immediate response of important range plants to grazing, but also the rapidity of recovery following vigor reduction. *Festuca idahoensis* of moderately low vigor required approximately 3 years and *Agropyron spicatum* 6 years of complete protection to approach normal vigor. Recovery from very low vigor may take more than 6 years of protection for *F. idahoensis* and 8 years for *A. spicatum*. Maximum leaf length can be used as a reliable index of *F. idahoensis* vigor, and a combination of flower stalk numbers and maximum lengths indicate vigor in *A. spicatum*. These findings stress the importance for the range managers to either avoid the over-use which depletes plant vigor, or else incorporate in their grazing plan the long period of rest or deferment needed to permit recovery. (203)

46. Rosaceous shrubs are important cover, stabilization, and animal food plants in the vast Intermountain shrublands. However, information necessary for management is lacking. The general vegetative, floral, reproductive, hybridization, distribution and habitat, and use characteristics were described and reviewed for several plants of the rose family. A taxonomic key covering each taxon was shown. Review and original information on important rosaceous shrubs are now readily available. (160)

47. Chenopod shrubs are important cover, stabilization and animal food plants in the arid Intermountain area as well as on millions of hectares of worldwide alkaline ranges. However, information necessary for management is lacking. The present state of knowledge, new observations, and original hybridization data have been summarized for several woody Intermountain species. A key provides ready recognition of taxa. Hybridization, distribution, and habitat and use are given for each species; also possibilities for breeding and selection are discussed. Review and original information on important chenopod shrubs are now readily available. (161)

48. The proper timing for lifting nursery-grown planting stock is an important factor in the ultimate success of revegeta-

tion efforts on forest and rangelands. A portable oscilloscope was developed to determine the level of activity or dormancy of nursery stock or plants in the field. Oscilloscopic wave form appears to be related to periods of plant dormancy and activity for the conifers and deciduous trees and shrubs tested. Several potential uses of this technique are suggested for nurserymen and research workers. Potential uses of this technique include evaluation of cold tolerance, assessing effects of storage on nursery stock, and determination of plant activity in vegetation control projects where growth stage is critical to success. (172)

49. Establishing shrubs on ranges dominated by cheatgrass brome is difficult if not impossible. Scalping 4-, 8-, 16-, and 24-inch widths in cheatgrass allowed four species of plants to establish in a stand of cheatgrass. In general, the wider width scalps favored better shrub establishment. Application of this method by land managers will provide shrubs in large stands of cheatgrass and improve habitat for wildlife. (178)

50. Revegetating disturbed areas is a crucial problem in the western United States. A list of plants suitable for revegetating depleted rangelands, mine and construction sites, logged and burned areas was prepared. Most encouraging results have been achieved when species were selected from plant communities that occurred near the problem sites, or have developed under similar climatic and edaphic conditions. This information will help managers in revegetating disturbed areas. (201)

51. More than three-fourths of the juniper-pinyon ranges of the western United States are severely depleted of grasses, forbs, and palatable shrubs necessary to thrifty big game herds. Indications from 20 years of study in Utah show that a competitive grass, forb, and shrub community in combination with browsing pressure is the key to preventing juniper and pinyon from regaining dominance on chained and seeded areas. This biological competition along with yet unstudied insects and diseases can make juniper and pinyon lands more productive for wildlife and livestock. (217)

52. Wildlife have not been adequately considered by economic analysis in forest management alternatives or in resolution of multiple-use conflicts in eastern forests. A technique was developed in the Monongahela National Forest of West Virginia using four species of game and seven major forest types. Timber/wildlife relationships were numerically rated for systematic consideration of management alternatives and to more accurately determine trade-offs between timber and wildlife values and between species of animals with different habitat requirements. This technique will assist the land manager in evaluating management alternatives and in showing the step by step logic of his decision to landowners and the public. (175)

53. Unknown variation in nutritive values of range forage represents a barrier to achieving efficient forage utilization. Information was provided on seasonal and locational variation in forage quality of numerous key grass, forb, sedge, and shrub species in central Oregon. The results obtained, together with the ranchers' knowledge of available forage, provide an improved basis for optimizing use of high quality forage through scheduling kinds and time of range use. Such results should also aid in alleviating the demand for late season protein supplementation. (182)

54. Lack of guidelines for managing lodgepole pine ecosystems throughout the Northwest for wild and domestic ungulates limits the development for optimum use of forest resources. Re-

lationships of timber harvesting techniques, understory production, and domestic and wild animal uses were summarized. Timber harvesting and cattle grazing practices were recommended to optimize ungulate productivity. (159,165)

55. Curleaf mountain-mahogany, although an important browse and cover plant for wild ungulates in the Northwest, is a species for which almost no management information is available. Germination capacity, possible causes of seed dormancy, methods of breaking seed dormancy, and initial seedling root and top growth relationships were determined. Relationships among curleaf mountain-mahogany ecosystems were examined, and habitat types, their phases and successional stages were delineated. It was also determined that the existence of this species and the communities it dominated were dependent on fire resistant rocky sites where old trees provided available seed sources in case fire decimated adjacent stands. Information from this study will enable managers to protect existing stands and encourage their expansion, as well as propagate new stands where desirable. (166)

56. Production of larger quantities of higher quality fruit is the ultimate objective in wild huckleberry management, but we need more information about the natural and cultural factors affecting huckleberries. Results of studies in Oregon and Washington show that huckleberries have numerous robust rhizomes that sprout vigorously after light surface fires, that huckleberries are susceptible to excessive micronutrients, and that sweetness of huckleberries is greatest late in the season but is apparently not affected by shading. This information should help forest managers devise cultural prescriptions that enhance the quality and quantity of huckleberry production. (198)

57. Prescribed burning is used in the southeastern United States to promote the growth of legume plants which produce seed important as quail food, but the basic effects of heat on legume seed germination are poorly defined. Moist heat increased germination of eight species and two varieties of legume seed while dry heat increased germination in seven species and two varieties. Thus, no broad prescription can be made for enhancing germination of all legume seed but prescriptions will depend on the species involved. (189)

58. The demand for red meat has stimulated interest in using pine-wiregrass forage for cattle production and in determining the nutrient content and digestibility of the forage. Crude protein appeared useful for predicting digestibility of grasses but not of forbs and shrubs. A comparison of *in vivo* and *in vitro* techniques to evaluate forage throughout the April to October grazing season resulted in similar findings. Poor quality of the forage was indicated by crude protein levels of less than 8 percent and dry matter digestibility of less than 40 percent during most of the grazing season. Land managers cannot rely solely on pine-wiregrass forage as a food source for cattle. (187)

### Fish habitat resources

59. The effects of chemical fire retardants on fish in streams is not known. A computational system that permits a rapid estimate of the amount of hazard to game fish was developed based upon (1) the amount of retardant that enters a stream and (2) the discharge rate and average velocity of the stream. Application of this system will allow assessment of the effects on fish habitat of retardants that may enter a stream during fire suppression activities. (730)



60. Measuring or weighing live fish can harm them. A photographic technique was developed for studies where fish were chronically exposed to toxicants, and changes in size and weight were one of the response measures under study. Actual dry weights of test fish were correlated with photographically measured indices of lateral area. The equation obtained has a coefficient of determination of 0.95, and the technique has been used successfully in tests of chronic oral toxicity. (227)

61. Fish spawning will be reduced if river bed conditions are not improved in the steep mountain lands in the Idaho Batholith. Research found that land uses in this sensitive area must be carefully planned to avoid adding more sediment to a stream than it is capable of transporting. A system of programmed land uses is recommended to avoid degradation of these aquatic environments. (228)

62. Containerized planting in the South has not been fully developed because of a lack of economic incentive. Results of several recent tests indicate containerization can meet the criteria necessary for full southern acceptance: an extension of the planting season, better early seedling growth, and an adaptability to automated planting. This information should serve as a stimulus and guide to those considering the use of container planting. (876,874)

#### Wildlife habitat resources

63. The effect of fire on wildlife is one question that has arisen with the introduction of prescribed fire into wilderness areas. Because of its position at the top of a food chain, the pine marten (*Martes americana*) appears to be a good "barometer" of the health of an ecosystem. Under natural conditions, fire does not maximize marten populations locally, but it does maintain sufficient forest diversity to perpetuate the species. Wildland managers would do well to consider the needs of the marten in comprehensive, long-range plans for the forest ecosystems it inhabits. (726)

64. Southern pine forest ranges commonly provide adequate forage for yearlong grazing by cattle and afford habitat suitable for white-tailed deer; however, the question of how intensive pine culture affects multiple land use has not been answered. In a study near Gulfport, Mississippi, cultivation and fertilization for pine revegetation not only increased pine growth at age 12, but browse desirable for deer was more abundant. Herbage production and browse undesirable for deer declined with cultivation and fertilization. With proper management, intensive pine culture appears to be compatible with browse maintenance. This provides encouraging evidence that multiple-use interests can be served with proper management. (293)

65. Profits largely determine management decisions on commercial forest lands. Past decisions have, therefore, favored timber production over wildlife, and land management practices advantageous to wildlife were usually incidental. The current trend in forest management in the South is to include game and charge for hunting. Most forest land owners have to be assured of a monetary return before making adjustments to improve wildlife habitat at the expense of timber. (246)

66. Because deer consume food at different rates and food-stuffs vary in quality through the year, the deer are hard pressed to maintain a nutrition level necessary for their optimum production. As early as November, deer may consume barely enough digestible dry matter to satisfy basal energy re-

quirements because of the low digestibility of many range forages and the diminished rates of food intake. Management practices that favor an increase of digestible dry matter, retention of fungi, hard and soft mast producers and desirable evergreen plants, and the establishment of food plots containing fertilized plantings of cool season herbages have demonstrable advantages to deer. (282)

67. Bachman's Warbler, an endangered species, is on the verge of extinction. An intensive search was made in I'On Swamp, formerly an important nesting area, and other portions of the Francis Marion National Forest. No birds were found, but much of the habitat appeared suitable for the species. The search, the most thorough ever made, emphasized to land managers and the public the dire status of the species. (247)

68. Forest managers need to know how different management alternatives affect wildlife habitats. A range analysis conducted in midsummer on adjacent clearcut and selectively cut areas in the Ridge and Valley Province of southwestern Virginia showed that plants preferred by white-tailed deer were 2.6 times more abundant in a 6-year-old clearcut as compared to an area selectively cut 5 years prior to measurement. Increased shrub numbers decline on the clearcut as the vegetation grows beyond reach of the deer, and the dense cover largely precludes development of understory vegetation. Thinnings are suggested as a means for maintaining browse production for these young forest stands. (231)

69. Whether to collect rumen samples to study the foods selected by deer from a particular area or rely on regionwide studies already completed is a question management biologists repeatedly face. A comparison between local samples within the Southeastern Coastal Plain of South Carolina and regional samples from sites between Florida and Maryland indicated that such a decision will depend on two factors: (1) The feasibility of collecting local samples, and (2) whether the biologist considers it important to know what specific plant species deer feed on. If the biologist is only interested in food categories, e.g., twigs, leaves, fungi, forbs, and grasses, regional collections are adequate. However, if the biologist must know the specific plant species deer feed on, local sampling will be required. It is essential to determine whether regional findings are applicable to local areas: (248)

70. In the Ridge and Valley Province of southwestern Virginia, acorns comprise about 70 percent of white-tailed deer fall and winter diet. In years of poor acorn production, however, it is important to know that foods are substituted. During poor oak mast producing years in southwestern Virginia, deer substituted large amounts of leaves of prostrate evergreen plants, shrubs, and mushrooms. Deer relying on mast-free diets had difficulty meeting minimum energy requirements for maintenance. The availability of acorns in the winter diet increased the estimated digestible energy to 3.1 kcal/g, a level adequate to meet the maintenance energy requirements. It is important that habitats be managed to assure an adequate supply of alternate high energy foods during times of mast scarcity. (252)

71. To improve deer habitat, the land manager needs to know what foods are available to deer over a range of forest types and conditions. Up to now, this information has not been available in the southern Appalachians. During the fall and winter months, a survey of 14 forest types on the Chattahoochee National Forest indicated the average yield of deer food was 109 pounds per acre.



Twenty pounds of the total were preferred foods. Forest types producing the largest amounts of preferred deer foods were loblolly pine, sweetgum-yellow-poplar, oak-hickory, and oak-pine. This information will aid in realistically determining carrying capacities of these forest types for deer. (250)

72. A study of the browse production on the Oconee National Forest in central Georgia indicated that during winter months the average yield of browse for all forest types was 143 pounds per acre, with 128 pounds contributed by "choice" foods and the remainder by "other" species. On an area basis, the sweetgum-yellow-poplar type produced the largest amount of "choice" species followed by the Virginia pine and loblolly pine types. Most important of the "choice" foods were Japanese honeysuckle and greenbrier followed by blackberry and blueberry. A knowledge of the relative values of forest types as deer range helps the land manager determine those types in need of habitat management. (251)

73. The common raven is a relatively scarce nongame species in the eastern United States that inhabits the narrow belt of mountains from northern Georgia to northern Pennsylvania. No quantitative data have existed on which to base management decisions concerning this bird. Density, distribution, food habits and habitat requirements were studied at several Virginia sites. This information provides a factual basis for planning additional research needs and making management decisions for a unique wildlife species. (249,254)

74. Construction of suburban areas often requires manipulation of natural vegetation. Information on wildlife population responses to changes in vegetation is lacking. Because landscaping is costly, such knowledge is important to planners and builders interested in providing a quality environment to homeowners. In Reston, Virginia, within four types of suburban habitats, the densities of breeding birds appeared to be directly related to the amount of shrubs. However, clumping of vegetation was thought to be more important than amount of vegetation in explaining variations between habitat in density. An inverse relationship was found between bird numbers and the amount of asphalt, cement and buildings. These relationships show that bird numbers are related to measurable habitat features. With better resolution of these relationships, planners can more confidently commit time and money to providing bird habitat where it is wanted. (255)

75. Snow depth limits availability of forage for deer on many winter ranges in North America. To decrease snow depths, carbon black was sprinkled on the snow in critical areas of deer winter rangers in Colorado. Snow melted to bare ground, exposing forage for deer 1 month earlier on the treated areas. This technique is a means of increasing forage availability to deer when they are in poorest physical condition and food needs are most critical. (274)

76. Logging in ponderosa pine is changing the environment of the Abert and Kaibab squirrels. Three studies in Arizona quantified the cover requirements of the squirrels in terms of basal area, trees per acre, size of nest tree, canopy coverage, and size of trees surrounding the nest tree. Forest managers can use the data to evaluate the quality of Abert habitat on 11 million acres of ponderosa pine in Arizona, Colorado, and New Mexico and of the Kaibab habitat on the Kaibab Plateau in northern Arizona. (241,265,273)

77. In recent years, the amount of wildlife literature accumulating in professional journals has made it difficult for field biologists to maintain a reference library. An alternative is to prepare bibliographies on subjects that are needed most. Such a bibliography, recently published, contains 390 references on research and management of important wildlife species and habitats in Arizona and New Mexico from 1913 to early 1975. This information provides the manager with a convenient desk reference to aid him in planning, environmental assessment and management of the wildlife resources. (266)

78. Information about requirements of cavity nesting birds was summarized for Arizona and New Mexico forests. Traditionally, dead or unmerchantable trees are removed during a timber sale because they are a fire hazard. Managers now have information that shows how important these trees are to maintenance of populations of cavity nesting birds. This information can be used in planning timber harvest, environmental analysis, visitor information, nature interpretations, and bird watching. (279)

79. The cottontail is an important food of many predators in the deserts of Arizona. Up to now, management of this species has been hampered by lack of information about the food and water requirements of this important prey. Moisture content and stage of growth of the plant apparently influenced food selection. Cottontail survival was found to be limited more by availability or abundance. With these new insights into the energy and water requirements, management of the cottontail in desert habitats is possible. (286)

80. Nutritional values of mule deer diets on southwestern ponderosa pine summer ranges were needed by foresters and range managers to evaluate impacts of timber harvesting on deer habitat. Chemical analyses and *in vitro* digestibility data were obtained for forages used by mule deer during the summer when the deer generally occupy ponderosa pine types. Nutritional quality of deer diets on ponderosa pine summer ranges declined sharply from spring to late summer. These declines were not severe enough to cause deficiencies. Overall, the nutritional quality of the summer diet of deer in ponderosa pine ranges was adequate. (224,288)

81. Sharp-tailed grouse need high energy foods to survive temperature extremes during winter. Relationship between cover requirements and loss of body heat have not been previously determined. A grouse in  $-20^{\circ}\text{C}$ . temperatures and winds of 8 miles per hour can, through changes in posture or cover, vary energy loss between 142 and 319 kilocalories per day. The bird uses dense vegetation or snow as insulation to reduce heat losses during extreme cold weather. Winter losses in grouse populations can be reduced if adequate winter cover is maintained. (240)

82. Elk in the Rocky Mountains are associated with timbered habitats; consequently, coordination between timber harvesting and management of elk is needed. Elk may move considerable distances to avoid disturbances associated with logging in the ponderosa pine forests of Montana. Research initiated in 1970 provides land managers with alternatives to minimize disturbances to elk during logging operations. (258)

83. Pocket gophers were thought to compete with livestock for forage in mountain rangelands of the Wasatch Plateau. Total forage production did not increase significantly on an area when gophers were excluded for 31 years. However, the kinds of plants growing in the area following gopher control were differ-

ent from those growing in areas inhabited by gophers. New gopher mounds provide suitable habitat for a variety of annual and perennial plants that are important livestock foods. The importance of the gopher in maintaining a variety of livestock foods in mountain rangelands has been determined. (185,260)

84. Techniques are needed to study behavior and movements of endangered timber wolves in Minnesota. Radio-tracking of wolf packs for several years provided much valuable knowledge. For example, we now know that the sense of smell is used by wolves to maintain a territory. These results provide the manager with information about wolf behaviour and management that will help ensure continued existence of the wolf. (271)

85. The wolf is a species threatened with extinction in the 48 contiguous States. The factors governing intrinsic population regulation in wolves are not well known. Males comprised 66 percent of wild wolf pups from a saturated, high-density wolf range in northeastern Minnesota, possibly reflecting disproportionate conception of males. Packs from areas of lower wolf density in other areas of Minnesota had equal sex ratios of pups or a slight but statistically significant preponderance of male pups. Study suggests that disproportionate sex ratio is related to whether or not wolf populations are near saturation level for the region. (262)

86. Managers need checklists of local fauna to make accurate environmental assessments, to develop land use plans, and to implement multiple-use management on public lands. The wild fauna in the Pinyon-juniper and Northern hardwood forest types have been described. This information is a basic step in improving planning and management of all wild fauna on forest and rangelands. (243,275)

87. To promote conservation of birds of prey, their role in nature needs to be understood. A study in Minnesota determined food habits, animal pest consumption, use of these birds as ecological indicators, and their value for recreational and esthetic enjoyment. This information presented to the public through this popular format should help lessen the continued serious persecution of raptors in Minnesota. (244)

88. White-tailed deer populations have declined in northeastern Minnesota from highs in the 1930s and 1940s in spite of ever intensifying forest management activities which should theoretically improve habitat. A recent study details fall and winter habitat selection forage preference during 1970 through 1972. Open cut-over and deciduous-dominated communities were used most frequently in early winter, and conifer-dominated stands, especially those containing balsam fir and white-cedar were used more frequently in late winter. Mountain maple, red-osier dogwood, and round-leaved dogwood were most used in late winter. This study suggests that this mature forest is producing sufficient browse and conifer cover to allow the diminishing deer population to overwinter in small scattered groups rather than concentrate in classic yarding situations traditionally observed in the area. (290)

89. In spite of the importance of bears as a recreation, esthetic, economic, and ecological resource, their biology and habitat requirements are known in only a very general way. Basic information about their biology, sociology, and food habits has been pictorially presented and the importance of a field research program on the bear detailed. These studies will provide information on the behavioral and physical adaptation and the environmental requirements of black bear to aid game and land

managers to assure the future of the black bear in the Lake Superior Region. (277)

90. Eventual scarcity of squirrel dens will ensue from most hardwood timber management systems unless they include ways to provide for den maintenance. Choice of the best way to manage for dens depends on intensity of the timber management and the acceptable degree of risk that a given way will not work. Standards for numbers and distribution of dens are recommended, and management options pertaining to four different levels of management intensity and risk are described. Although the options are designed primarily for even-aged forests, the two more-intensive options can be applied in any forest stands where dens are needed. (278)

91. Many mule deer herds have low reproductive rates because range conditions have declined from overuse. In southern Idaho, deer and livestock numbers were reduced to range carrying capacity and fawn production increased as range conditions improved. Average fawn production increased 47 percent among yearlings and 42 percent among 2-year-olds and averaged 20 percent for all age classes of does combined. Managers can use this information to gain public support for reducing livestock and deer on overstocked ranges. (259)

92. The effect on mutton of spraying DDT to central forest insects is unknown. DDT residue was sampled in weaned lambs grazing in mixed conifer forests aerially sprayed with DDT to control Douglas fir tussock moth. DDT residue was highest in fat of lambs grazing sprayed herbage for 2 weeks; residues then decreased in lambs grazing for longer intervals up to 16 weeks. Residues in lambs grazing sprayed herbage for longer periods did not fall below acceptable tolerance levels after 18 weeks on unsprayed herbage. These results will aid administrators and stockmen in future planning of livestock grazing practices on forest ranges which may require application of chemical pesticides. (284)

93. To diagnose the health of wild animals, field biologists are using techniques and equipment developed by medical researchers. Cooperative studies between these two groups are providing new insights into understanding relationships between the general health of wild animals and their environment. For example, twelve common tests of human blood samples were effective in diagnosing the general state of elk and moose (wild mammal) health. This new research approach holds considerable promise of providing the concepts and tools for evaluating the condition of wild animals and the condition of their range relative to their needs. (230,257,269)

94. Nongame birds have been a neglected ecological and recreational resource, which until recently, have not been seriously considered in decisions on land management. Initial guidelines for management of forest and range habitats for nongame birds have been developed for many locations. Twenty-eight state of knowledge summaries about management covering a variety of special topics and major ecosystems including interactions between people and birds; bird behaviour and habitat management; the influences of forest and range management practices on bird populations; and agency management programs for nongame birds. These results provide managers, biologists, planners, teachers, and the general public with authoritative summaries of how to manage forest and range habitats for nongame birds. (204,222,226,256,283)



95. Guidelines for red squirrel management in white spruce forests of interior Alaska are not available. Population response of red squirrels to clearcut and shelterwood silvicultural systems in interior Alaska was determined by counting the population before and after cutting. Following harvest, all territories from the clearcuts were vacated and the number of squirrels in the shelterwood decreased from 1 per 0.69 ha to 1 per 2.0 ha. The squirrel population in the adjacent control area and along the cutting area boundary remained stable. These comparisons help define management alternatives and resolve trade-offs among them. (292)

96. Moose are an important resource in Alaska and evaluations of browse production and use are needed to assess moose habitat. On the Tanana River flood plain near Fairbanks, 38 and 113 kg/ha of available hardwood browse were present in 8- and 15-year-old stands respectively. Moose consumed about 55 percent of the available forage in both areas during the winter of 1974-75. Willows were the most abundant shrub and in turn provided the most winter forage. These evaluations help establish moose management guidelines. (291)

97. Although cultivation and fertilization can increase growth of southern pines, questions have existed concerning the effects on understory vegetation. In a pine plantation in Mississippi 12 years after cultivation and fertilization treatments, deer habitats were better than on the control. Browse species became more plentiful and reduction of undesirable browse improved accessibility for all forest users. Thus, intensive pine culture and browse management seem compatible throughout much of the southern pinelands. (293)

#### Rangeland management

98. Multiple use of the southern pine forests requires complex planning. Range and wildlife resources were described and related to forest management practices. Site preparation, reforestation, thinning, clearcutting, prescribed burning, and fertilization techniques provide single- or multi-resource yields, depending on the land manager's objectives. Judicious multiple-use planning provides benefits to cattle and wildlife with few concessions necessary from lumbermen. (305)

99. Forbs comprise a large proportion of the total herbage on many high elevation cattle ranges in the Bighorn Mountains of Wyoming. Many managers consider them to be undesirable forage for cattle, and herbicidal control of forbs is an accepted range management practice in this region. This study showed that while 2,4-D significantly increased the ratio of grasses to forbs in the herbage, it did not influence total herbage production. Yearling steers grazing the treated ranges had the same grass-to-forb ratio in their rumen as steers grazing untreated ranges, and daily weight gains were also similar. The lack of a significant increase in forage production, of alterations in the composition of the steers' diet, and in their weight gains indicate forb control is not necessarily a desirable range management practice, especially under light rates of stocking. (221,310)

100. Because of the high cost of southwest semidesert ranch property and the large unpredictable variation in forage crops, range livestock production appears questionable. Research found that proper stocking can make a ranch operation stable, simple, income producing, and of reasonable risk. Ranchers in Arizona should be encouraged to continue to graze livestock on semidesert range. Forage on these ranges uses solar energy and

the forage cannot be harvested economically by machine. Therefore, the most efficient use of the forage is grazing livestock. (301,302)

101. The dormant plant period from fall through early spring is the most critical period for adequate livestock feed and also the most expensive because of the need for supplements. There is a need for plant species and management systems which can reduce supplement feeding costs or provide better livestock maintenance. Cattle, grazing Sherman big blue grass ranges in Colorado during the cold winter period, gained weight in late fall with or without a protein supplement. During late winter and early spring, they lost some weight. Big bluegrass could be used for fall grazing to replace native range. The native range is then used for better winter and spring livestock management. Costs are reduced and more animals can be carried over winter or a fixed number of animals can be maintained on fewer acres. (295)

102. Sheep numbers permitted on high mountain ranges have been declining for several decades because of conflicts with watersheds, wildlife, and recreational values. Investigations into the possibility of utilizing traditional spring-fall range on the Upper Snake River Plain in Idaho for summer grazing indicated that sagebrush-grass range can withstand heavier grazing pressures in the summer than in the spring. Heavy grazing (80 SD/A) was more damaging to grass and forbs in early summer than in late summer. Moderate grazing (30-40 SD/A) over a 5-year period did not adversely affect the vegetation, and maintained ewe weights. Summer grazing of sagebrush-grass range can provide ranchers with opportunities for maintaining or increasing sheep numbers despite restrictions on high mountain ranges, if they have an excess of spring-fall range. (298)

103. The western sheep industry is limited by the increasing constraints imposed on grazing high-mountain summer ranges. Studies on the Centennial Mountain range in Idaho show that traditional spring-fall range can be grazed profitably by sheep during the summer months if the lambs are weaned early in July and placed on green feed. Over a 5-year period, ewes grazed on sagebrush-grass range gained about 5 lbs. during the summer while those on high-mountain summer range gained about 10-15 lbs; however, these body weight differences were negligible the following spring. Wool production was not affected. Summer grazing of spring-fall sagebrush-grass range by sheep appears both a practical and profitable option for alleviating shortages of traditional high-mountain summer range. (307)

104. Grazing inevitably alters, to varying degrees, wildland vegetation and it is primarily by the establishment of protected "natural areas" or reference areas, that we are able to maintain representation of undisturbed plant communities to serve as a basis for judging the effects of man's perturbations. A new publication reviewed the literature regarding rangeland reference areas, summarized current programs in the United States and Canada, and outlined a program to encourage establishment and preservation of such areas. It serves as a course of information for those interested in the preservation of rangeland natural areas. (299)

105. Ponderosa pine-bunchgrass ranges have been grazed for over 100 years, yet no systems or levels of grazing have been prescribed for resource managers. An 11-year study of plant and animal responses to systems and levels of cattle grazing snowed forested range was improved by deferred rotation; there was



little change on intermingled grassland openings. Big game use decreased as cattle stocking increased. *Carex geyeri*, the most valuable forage, was favored by light deferred rotation. Range managers have six alternative grazing methods for ponderosa pine-bunchgrass range management with identified impacts and trade-off values for associated resources. (308)

106. Ranchers need additional information on livestock performance on ponderosa pine ranges. Responses to cattle grazing in eastern Oregon under three levels of stocking were compared. Levels of stocking produced different degrees of forage utilization but grazing systems did not. As stocking increased, herbage production and cattle gains decreased. Systems of grazing had no effect on cattle gains. Deferred rotation improved ground cover in the grassland type, but had little effect on yield. In the forest, yields of forage were diminished by season-long grazing compared to those under deferred rotation. The results will aid range managers in forecasting the results of investments in improved woodland grazing techniques. (309)

107. Implementation of available knowledge of range management techniques in the central and southern Rocky Mountains has been slow because publications were scattered or incomplete. Comprehensive, in depth reports have been prepared for seven important range types in this area. These reports summarize published information applicable for range management of the seven range types. They also contain valuable knowledge accumulated through experience and familiarity with specific range situations. Information from these reports will permit better range management in this area. (163,190,220,296,303)

## IMPROVING SOCIAL AND AMENITY VALUES

### Environmental amenities—landscapes and open space

108. Good communication in land-use planning requires common agreement among the various disciplines involved about the meanings of relevant terms and concepts. A glossary has been designed to facilitate a common understanding and acceptance of the meanings of current wildland planning terminology. The glossary contains definitions of 1400 terms—with 600 other terms cross-referenced to more preferred usages. The glossary provides a ready reference source where planners and managers can keep pace with the evolution of wildland planning terminology. (323)

109. Land management to enhance or protect esthetic values requires procedures for delineating the terrain visible from one or more points in the landscape. Research has developed a computer program called VIEWIT, that analyzes the slope, aspect, and area that can be seen from selected locations. The information is printed on a map overlay that makes it easy to compare VIEWIT results with other land-use planning considerations. The system may be used by those having remote terminal access to the USDA Fort Collins Computer Center. VIEWIT has been used to plan timber harvesting operation, scenic trainways routes, transportation system alternatives, recreation developments, and fuelbreaks. (325)

110. Multiple-use of the lodgepole pine ecosystem requires an understanding of how the species should be managed to enhance esthetic quality. Individually and collectively, lodgepole pine

tends to be modest and unassuming in its visual composition. Research has shown how esthetic values increase when the species is integrated with other elements of the landscape. Lodgepole pine is frequently associated with Rocky Mountain landscapes and thus results of this research have applicability for improving esthetic quality over a wide geographic area. (313)

111. Planning for recreation and other uses requires projections about the future. Using the Delphi research technique, a panel of 400 experts provided forecasts of 125 future events about the Nation's natural environment. These perspectives on the future provide a basis for dealing more effectively with future environmental problems. (319)

112. Europeans are ahead of the United States in land use zoning to maintain a range of conditions and opportunities. Europe's small-scale and highly humanized landscapes often have such coarse visual textures that timber cutting blends into, rather than mars, the scene. Furthermore, cutting areas are usually so small that stands of many ages are often visible from a single point—making the sustained nature of timber management clear to even skeptical viewers. The European experience shows that lands can be managed for high levels of both amenity and material benefits. (326)

113. Planning for recreation and other land-uses is a complex task. Analysis of land-use planning processes in Holland suggested that the required decisions need to involve the interaction of five groups: diverse specialists, interest groups, analysts, planners, and decisionmakers. For best results, participants must understand the limits of their roles, and communication among the groups must emphasize the meaning (rather than the details) of related data. A computer mapping technique for identifying and defining land-use alternatives is described. The method is applicable to many land-use planning situations in the United States. (327)

114. For much of the world, recreation must be subordinated by more pressing priorities. Analysis of the situation indicates that poor nations cannot justify substantial sacrifices to gain international tourism, to maintain options involving recreational lands for a later stage of economic development, or to preserve land-based examples of a national heritage. Analyses such as these can help set priorities in international forestry and land use planning. (328)

115. Land management requires procedures for monitoring changes in land-use patterns. Research has described the changes in vegetation and land-use in Massachusetts for the 20-year-period 1952-72. The research describes a system for classifying land from aerial photography. Areas as small as 3 acres were classified in 28 broad types and 104 detailed types of land areas. Statistics and maps are available for land-use planning at the town, county, and State levels. (314,315,316,317,318)

116. An important aspect of recreation demand, and one that consumes significant parcels of attractive natural landscapes, is the second-home recreation market. Rapid growth in the construction of second-homes in the Northeast has had significant positive impacts on the economy, and negative impacts on the social and environmental aspects, of rural areas. Research has shown that second-home development clearly accelerates change in land-use away from farming and forestry. Policy issues and additional research-needs are identified for future planning and research. (321)

117. Land use planners in and around urban centers need efficient techniques to manipulate and analyze the huge amounts of data involved in planning decisions. Research has developed a *Metropolitan Planning Model* that allows planners to analyze areas threatened by natural and man-made hazards, and to define areas that are specifically suited for development without undue degradation to the ecosystem. The model can be used to predict land use trends resulting from planning decisions from urban sprawl, and therefore, is extremely relevant to decisions related to the social and economic well being of people in densely populated areas. (311,312)

118. Growing demands on land resources have resulted in the problem of how to best allocate land for various combinations of uses and benefits. Interviews with Connecticut residents provided the basis for defining degrees of public acceptability toward existing land uses such as open land, forest products, agriculture, mining, recreation, wildlife, and rights-of-way. The results provide a useful evaluation of public acceptance for various land use policies. (324)

119. Increasing public awareness, and resultant legislation, has put forth a challenge to planners, designers, and scientists to insure that intangible or amenity-values enter into the landscape decisionmaking process. Results of 21 papers comprise a state-of-the-art report on landscape values, perceptions, and resources. Results can be used by land planners to better identify and incorporate landscape values in regional plans involving a multiplicity of resource management interests. (329)

120. Traffic noise is the most widespread form of audio pollution and attempts to reduce it at the source have been only partly successful. Tests in Nebraska show that wide belts of tall, dense trees can reduce sound levels up to a half and combinations of tall dense trees, shrubs, and landforms 10-12 feet high can reduce it as much as two-thirds. Sound barriers close to the sound source were more effective. Effectiveness of tree-covered landforms is now qualified and is being used by landscape architects, highway engineers, foresters, and other to reduce noisy traffic situations to more acceptable levels. (805)

#### Environmental amenities—wilderness

121. Increasing use of remote backcountry recreation sites in the Northeast is resulting in a loss of the thin soil mantle and destruction of the ground-cover vegetation. Fencing, fertilization, and liming—plus various combinations of these treatments—were tested as a means of reestablishing ground-cover vegetation on bare mineral soils. Results indicate that a combination of fertilization, liming, and fencing was the best treatment for restoring ground vegetation. (330)

122. In order to determine management strategies for the interior zone of the Boundary Waters Canoe Area in Minnesota, knowledge of the composition, structure, and relationships of the plant communities is needed. Research has identified the major upland plant community types in 68 stands disturbed by logging and in 106 undisturbed stands in the area. Managers not only can use this information to evaluate possible management strategies within the area, but also to relate ecological information to stands outside of the area—and thus broaden the management implications of the data. (331)

123. Management options for the Boundary Waters Canoe Area in Minnesota require ecological information about plant communities, their development, and the wildlife they produce.

Scientists have summarized both the vegetation and wildlife research results since 1967. Results indicate that composition of the plant communities is largely determined by: time since last disturbance, composition of the disturbed community, and severity of that disturbance. Overall vegetation, predators, and prey are all adapted to a pattern of recurring disturbance by fire. The results provide management with a clearer understanding of the factors that influenced present conditions, and thus a firmer basis for managing these environments in the future. (335)

124. Efforts to determine desirable modifications of wilderness use patterns through on the ground trial-and-error are time-consuming, often inconclusive, and generally inefficient. Research has developed a tool that enables a manager to test a variety of possible policies in a short time with a simulation model. Detailed information on use patterns and congestion enables evaluation and comparison of alternatives. This user's manual describes three versions of the model and presents the computer programs required to operate the model, which is a useful, practical tool for wilderness management. (336)

125. Management efforts to modify wilderness use patterns need some way of measuring actual use to identify problem areas and determine the success of attempts to shift use. A study of use patterns in part of the Selway-Bitterroot Wilderness in Montana discovered that unmanned trail registers, a very common way of gathering use data, are much less reliable than thought. Only 28 percent of the visitors registered. Day-use and horse use would be particularly underestimated by trail register data. Trail register data need to be viewed suspiciously and used only after field checking. If the low compliance rates found in this study are widespread, alternative ways of obtaining reliable use information will need to be developed. (333)

126. The demand for hiking has been growing rapidly at the same time hiking opportunities have been declining. Short trails, close to population concentrations and zoned to separate mechanized and unmechanized visitors, seem to be most needed, based on a review of research knowledge about trail use and users. (334)

127. The impacts of recreational demand on the user and the resource of the Boundary Waters Canoe Area of Minnesota are a major concern of resource managers. Analysis of the situation indicates that heavy use and congestion are confined to specific locations and time periods, and that paddle canoeists strongly object to meeting motorized parties. Results are helping planners to understand patterns of recreational use and what to do to minimize dissatisfaction among user groups. (332)

#### Managing recreational opportunities

128. Accurate knowledge of the camping market is increasingly critical for successful development and competitive operation of commercial campground enterprises. Based on a nationally representative sample of 2,313 households, the total camping market is estimated to include 14.3 million households of active campers, 6.1 million who are temporarily inactive, and 6.1 million who are potential additions to the market. Research has documented the popular image of camping as held by each of the major segments of the market, and has examined the reasons why households permanently or temporarily drop out of the camping market. This information is vital to present and potential campground market investors and operators. (347)



129. Pricing of outdoor recreation services is an important policy issue for public agencies and a major factor in commercial recreation enterprises. This study at a State park in New Hampshire examined the effects of charging premium prices for waterfront campsites. The premium rates increased park earnings by 29 percent, while the use of waterfront sites declined by only 4 percent. If a similar program of differential fees were applied throughout New Hampshire's 212 commercial campgrounds, the estimated increased profit would be almost half a million dollars. (348)

130. Demand for water-oriented outdoor recreation continues to increase—especially near urban areas. Consequently, municipal watershed managers are under pressure to open their watersheds and reservoirs for recreational activities. Problems and opportunities are reviewed for watersheds on which varying amounts, to no amount, of recreation is permitted. Information is provided that managers can use to develop contingency plans for various alternatives regarding recreational opportunities on their land and water resources. (345)

131. Managers continually seek ways to clarify and improve the decisionmaking process in recreation-resource management. Based on results of a survey of 29 top decisionmakers, four broad areas are involved in such a process. These areas listed in ascending order of difficulty to contend with, are: political influences, characteristics of the physical resource, supply opportunities, and recreation demand projections. Information provides insights into management priorities and related research needs. (350)

132. Although interpretive presentations can greatly enhance the recreation experience, methods have not been available to evaluate the effectiveness and to identify opportunities to improve these presentations. Tests have shown that field personnel can observe and record level of effectiveness and audience attention to various kinds of presentations. Results can be used to help diagnose strengths and weaknesses of such presentations. (341)

133. To be effective in interpretation of natural environments means to create desired effects in an audience. Research has described how to clearly specify what those desired effects should be, how to design messages to attract and hold the attention of the intended audience, and how to evaluate how well the desired effects are accomplished. The results are applicable over a wide range of environmental interpretation situations. (356)

134. To gain a better understanding of public reaction to information and education displays, average viewer time was measured for a variety of exhibits. The longer the message per exhibit, the less time was spent observing it. Study results are intended to assist professionals in the design and presentation of exhibits about people's relation to their forest resources. (353)

135. The economic value of nongame birds is often overlooked in urban development program. Research has shown that in 1974, expenditures for birdseed, binoculars, feeders, books, field guides, and camera equipment, amounted to 500 million dollars. Results provide information to justify the preservation and enhancement of wildlife habitats for nongame birds in urban environments—where the potential for wildlife enjoyment through bird watching is enormous. (340,351)

136. More open space is needed for urban residents, and greater public involvement is needed in urban resource management decisions. Research has found that members of minority

groups lack the influence and expertise to participate effectively in resource decisions that affect their well being. Forestry professionals should work actively to increase minority participation in forestry-related issues. (357)

137. Urban planners need to know the economic value of trees on land available for residential development. Professional appraisal of simulated combinations of different amounts and distributions of trees on a 12-acre parcel of land showed that trees can account for as much as 25 percent of the total value. Scattered arrangements of trees were valued more highly than concentrated arrangements. Results strongly suggest that trees should be retained when wooded land is developed for residential use. (322)

138. In order to properly manage a river for recreational activities, it is necessary to understand the conflicts that may arise among various types of recreationists who use the river. For the Au Sable River in Michigan, research has shown that the main causes of conflict among canoeists, fishermen, and other river users, were: 1) Excessive numbers or distributions of users, 2) different objectives among users, and 3) behavior of users. Canoeists, for example, often are not aware of the effect of their presence on fishermen and fish. Management alternatives suggested by various users provide a range of options for river recreation management. (343)

139. New problems have been created by the increased number of people engaged in river recreation. Studies have shown how patterns of river use and characteristics of users vary among rivers, how current users define a high quality river recreation experience, and the kinds of management techniques that will best increase user enjoyment. This information helps scientists focus on future river recreation research efforts and needs. (349)

140. Recreation is too socially important for policy makers and managers to continue to rely primarily on intuition to govern most decisions. For this reason, research has examined why a person participates in a recreational activity, what that person does while participating, and the effects of personal and environmental influences on the recreational behavior. Conceptual models have been developed for defining and measuring recreation demand in behavioral terms. The model presented is applicable nationwide to recreational planning and management. (344)

141. The Forest Service must estimate the demand for and value of outdoor recreation opportunities in the Salt-Verde Basin of Arizona in order to efficiently administer the National Forests in the Basin. A modification of the Clawson—Hotelling approach to estimating recreation demand was employed to generate resource values by both the consumer surplus and nondiscriminating monopolist methods. Higher net values and larger expenditures were associated with sites that: have water-based recreation, considerable development at the sites, and fairly easy access. The nondiscriminating monopolist value for the entire Basin is estimated at \$36,376,487 and the consumer surplus value is estimated at \$78,438,193. Such values facilitate putting recreation on a comparable basis with other dollar-valued forest outputs. (355)

142. Better information is needed on the goods and services desired from outdoor recreation resources. The psychological basis of outdoor recreation demand is examined and results of selected research on quantifying those demands are interpreted. Results show how recreation demand information can be ob-



tained in a wide range of resource management situations. (342)

143. Public response to resource managers' requests for citizen participation in resource decisionmaking has increased to the point where managers need an objective, systematic procedure for analyzing that input. A specially adapted content-analysis system called *Codinvolve* was developed. The system has been utilized in a variety of land-management issues involving thousands of citizens responses. Four case studies are discussed which demonstrate the flexibility of the system and how it is applied. Problems in applying *Codinvolve* are discussed as well as reactions to it from both managers and the public. This system will aid managers in summarizing large amounts of complex input. (383)

144. Guidelines for campsite spacing and location in roadless areas to achieve certain standards of user isolation are an important management issue in wilderness and backcountry recreation management. Spacing guidelines are given to achieve proposed levels of sound insulation for three kinds of roadless settings based on remoteness—pristine, primitive, and portal—and for meadow, woods, and streamside locations in each. The guidelines were derived from field tests and theory explaining how far noises will carry as affected by environmental factors such as landform barriers, screening, and background noise. These findings now allow managers to determine how many campsites can be allowed and how they might be optimally located in roadless area settings, to achieve three alternative standards of noise insulation. (339)

145. Applied social research can help improve procedures for collecting, analyzing and evaluating public input to resource decisions. Research has indicated that administrators often didn't know about existing social research that has direct implications for their efforts to involve the public. Research has identified some operational problems of administrators in securing public participation in decisionmaking for which applied social research might be helpful. Social researchers are urged to become involved with decisionmakers in public participation projects as a means of identifying how social science concepts and methods might be helpful. (354)

146. Answers are needed concerning effects of recreation on water quality in wildland areas. A study in north central Colorado indicated recreational use alone was not a significant cause of bacterial water pollution. Water pollution appeared to correspond with camper reaction to public opinion and to the type of camper using a campground facility—low density use and corresponding low visibility may encourage some campers to pollute; backpack campers produce less pollution than campers using motorized vehicles. The study suggests the need to prevent vehicular approach to water bodies near campgrounds, to provide adequate toilet facilities, and to better instruct users of motorized campers about proper waste disposal. (337)

147. The rapidly increasing number of vacation homes and recreational developments near National Forests could seriously impact associated water resources. Studies in northern Arizona suggest that dispersed, well-designed, and well-maintained soil disposal systems at suitable locations are well adapted to the forest environment and adequately protect water resources. Conventional sewage treatment systems are not recommended unless unsuitable soil conditions or high density populations pre-

clude the use of soil treatment and individual disposal systems. (352)

## ENVIRONMENTAL TREE CULTURE

148. Introduced trees have enriched the environmental quality of communities, recreation areas, and roadsides throughout the world; but these introductions are frequently unsuccessful. A recent report by the Rocky Mountain Forest and Range Experiment Station summarizes information identifying many critical factors such as seed origin, climatic and edaphic conditions, mycorrhizae, insects, disease, and animal factors that affect the health and vigor of introduced species. This summary can serve as a reference guide in making wise species selections of nonlocal trees. (806)

## ECOLOGY AND CLASSIFICATION OF NATURAL VEGETATION

149. People interested in trees often do not get the information they want. A popular, but accurate, account of some major tree species has been presented in a widely circulated magazine. This will assist homeowners and others in tree identification. (804)

150. Frost heaving is a leading cause of tree seedling mortality in many parts of the world. Studies in Arizona show that the rate and amount of frost heaving increases with increasing bulk density, that indexes utilizing bulk density and sand content of the soils are useful predictors of frost heaving susceptibility of forest soils, and that measures which lower bulk density, such as plowing or disking, reduce heaving. These results help the forest manager detect where tree regeneration may be adversely affected by frost heaving and offer some possible measures for reducing this damage. (743, 752)

152. Natural areas serve as a base for evaluating silvicultural studies as well as many other functional activities, but the limited representation of many biological and physical phenomena curtail their use to date. A systematic approach has been proposed for building a system of natural areas for Montana. Classification schemes for five natural phenomena groups—forests, grass and shrublands, aquatic, zoologic, and geologic—were developed to serve as a basis for building a complete and representative system of natural areas. This system is used as the guide for natural area work in Montana and could serve as a conceptual framework in other areas as well. (751)

153. Research Natural Areas (RNA's) are essential as sites for basic and applied ecological research, but there has been no master plan for guiding the selection and establishment of new RNA's. A comprehensive plan was developed for a minimal system of RNA's in Oregon and Washington. It includes consideration of the terrestrial, aquatic, and marine ecosystems and rare and endangered species. The plan will facilitate selection and establishment of RNA's without danger of misdirected or overlapping efforts by the many groups involved in this work. (738)

154. A system of classifying forest lands into units of like biological potential, and a better understanding of the ecology of these units, is needed as a basis for research and management in the Rocky Mountains. Classifications for the major forest vegetation types in portions of Wyoming, Idaho, and Montana are now available. These classifications include keys for field identi-

fication, environmental data, vegetation composition, and discussions of land-use implications. These classifications provide new scientific knowledge on forest vegetation and environment as well as a solid ecological foundation for forest management practices. (737,747,755)

155. Effects of seasonal, climatic, and edaphic factors on the frequency and development of mycorrhiza-producing spores are poorly understood. Spore populations and the extent of mycorrhizal infection of wheat roots in Pakistan with fungi of the genus *Endogone* were influenced by soil depth, texture, and water-holding capacity; by pH, organic matter content, and available phosphorus; and by season and the developmental stage of the crop. Knowledge of these relationships may eventually lead to management of these important symbionts for optimum herbaceous and woody plant production. (750,752,785)

## IMPROVING ENVIRONMENTAL QUALITY THROUGH FIRE MANAGEMENT

### Fire prevention, hazard reduction, and prescribed burning

156. Techniques for spraying chemicals on small test plots must produce a uniform and reproducible spray pattern that simulates the treatments of large-scale operational spray-jobs. Specially designed equipment is required for controlled herbicide applications over tall brush. A tripod-supported pneumatic pressurized boom sprayer was developed and has been used on shrubby vegetation on hundreds of plots. The volume of spray applied per acre can be readily changed. The sprayer will be of interest to researchers everywhere who have responsibility for applying herbicides to tall brush. (678)

157. Because of high fire danger in California, it is important to identify high fire-risk forest using publics. In this study, age, sex, education, and income were most closely related to variations in knowledge of and attitudes about fire, fire behavior, and forest activity. Youths and persons 65 years old or older who have limited education and income were identified as high risks. For increased prevention effectiveness, fire prevention administrators in northern California should design programs with this group in mind. (677)

158. Forest residues in the Pacific Northwest usually require treatment to meet land management objectives. Over 200 guideline statements were developed by experts in various land management disciplines to help land managers apply technical and research knowledge in achieving these objectives. A unique keying system is provided for determining which guidelines apply to each planned management activity on a given site within a given forest species association type. Application of these guidelines can materially improve the quality of residue management on both public and private forest lands. (683)

159. Forest residues are a fire hazard, an obstacle to regeneration, and, in some instances, wasteful. Dragging a high-lead scarification device through cutover areas was found to be a suitable treatment for small diameter residue or brush; burying was determined to be feasible in special situations, such as roadside cleanup or recreation area development. However, efforts to speed decomposition by applying chemicals have been disappointing. On the utilization side, less residue was found following the sale of small, low grade material on a per-acre lump-sum

basis than when the sale was on a scale basis. Incorporating this information into land management planning will help assure the soundness of decisions. (679,685,687,688,689)

160. Increased use of prescribed burning could be facilitated in areas with fragile soil or high fire hazard if the need and costs for building standard control lines could be reduced. A survey of fire management specialists of National Forest Regions indicated a semi-permanent fire retardant would have potential in prescribed burning and along high-use roads in critical fire hazard areas. The findings suggest that an attempt should be made to develop an economical semipermanent retardant. (681)

161. The effect of heat from prescribed fire upon seed germination is not well understood. Seed from several leguminous species that are important sources of quail food were laboratory tested for heat response. In about half of the species, germination was increased by moist heat—the type produced by a forest fire. The seed coat appeared to be the factor responsible for excluding water and maintaining dormancy in the other species tested. Future research should reveal the field conditions under which a fire produces heat and moisture that are optimum for germination. (680)

162. Knowing the personal characteristics of effective fire prevention contractors would assist in hiring and placing personnel in these jobs. A study of prevention personnel in the North Carolina Forest Service indicated that effectiveness was positively related to ability to communicate, acceptance of self and others, achievement orientation, and motivation toward self-improvement. The North Carolina Forest Service was provided a simple test for measuring these attributes in potential employees. (675)

163. Unsuccessful fire prevention efforts often are based upon insufficient information about the fire-setters they are directed against. This study found that persons who had started fires deliberately usually were indigenous, young, married, white males with some high school education and poor financial records but no criminal record. Persons who had started fires accidentally generally were older and less educated than the incendiaries, but otherwise quite similar to them. This study is a requisite step in the process of developing guidelines for evaluating man-caused fire problems for prevention planning purposes. (676)

164. In order to be of optimum benefit, the findings of individual fire prevention studies must be synthesized, interpreted, and used as a basis for recommending action. Ten years of sociological analysis of the South's incendiary fire problem clearly establishes the deep roots of the practice in certain rural sub-cultures. This fact suggests that a significant and lasting change of the picture could be effected by a program directed toward the source of the problem; a community development approach is recommended as such a program. This information will be used in conducting and evaluating an experimental development program in an area of high incendiaryism. (672)

165. A relationship between the amount of duff burned in prescribed fires and the overall heat release (or intensity) involved in the surface fire has been presumed more or less explicitly in the fire research community. A detailed review of data gathered during a series of prescribed slash fires was undertaken in an effort to quantify such a relationship. The failure to discover any such relationship implies a much weaker connection



between these measures of fire behavior and effects than often has been presumed. Further research is recommended. (669)

166. Prescribed broadcast burns in the intermountain West do not always meet desired objectives; erratic results often are produced. An equation has been devised for predicting duff depth reduction from upper duff moisture content and buildup index. Total fuel reduction can be estimated using the same variables along with preburn weight of 1-10cm fuels. A fire manager can greatly increase the probability of a successful burn by considering these results. (671)

167. Mesofauna of the forest floor benefit tree growth indirectly by their involvement in organic matter decomposition, yet the effects of cultural practices on the fauna are not well understood. In a study in South Carolina, the population of *Collembola* decreased with annual burning, but not with burning every 5-8 years. Prescribed burning (both annual and periodic) increased the species diversity of *Collembola*. Because complexity insures stability within ecological systems, cultural practices that simplify forest ecosystems should be used cautiously. (725,728,729)

#### Fire management methods and systems

168. Damage resulting from a forest fire is little understood, highly complex, and inconsistently evaluated between various agencies. The need for a standard fire damage appraisal system on all federal lands was illustrated by applying two agencies' appraisal criteria to one fire with considerable differences resulting. Forest fire control agencies must use proximate criteria for damage appraisal until research in economics-based evaluation can be completed. (706)

169. Until 1972, fire location information on the Forest Service's Individual Fire Reports was not suitable for quantitative analysis. A computer-based technique called the Regional Area Mapping Procedure (RAMP) was developed which converts locations expressed in section-range-township notations into latitude-longitude coordinates. Not only does RAMP allow retrieval of important historical fire data, but the technique can be applied to other types of land-management problems. (705)

170. Transmission of infrared imagery from a fire-mapping aircraft to a fire camp has always required physical transfer. Now a telemetry technique has been developed which allows transmitting infrared imagery from an aircraft to the fire camp in near real-time. This technique offers an effective means of providing the fire boss with accurate, up-to-the-minute information about the fire. (710)

171. Fire planners need to know where to obtain fire weather information, and they need seasonal guides for proper allocation of firefighting resources—regionally and interregionally. A map showing the location of all fire weather stations in the northeastern and northcentral United States now is available, and the average dates of greening and curing of herbaceous plants, annual profiles of peak fire activity, median size of fires in various fuels, and other measures of fire activity have been documented. This kind of information allows fire planners to set objective limits on fire season and to compare actual fire occurrence with that predicted by fire danger rating systems. (693,698,699)

172. Because the cost of direct suppression increasing at an alarming rate, alternatives such as fuels management must be seriously explored. Research in the northeastern United States indicates that establishment of hardwood fuel breaks using en-

demio species is a promising fuels-management practice. A study in Missouri established the lower and upper limits of organic matter on the forest floor under a 40-year old, fully stocked oak stand. Other research indicates that the amount of slash fuel present after cutting Northern Red Oak (*Quercus rubra* L.) can be predicted using diameter at the base of the crown. Either used directly or as input into the National Fire Danger Rating System, this kind of information enables fire managers to evaluate their alternatives in a more objective manner than before. (701,702,703)

173. Fire managers find it difficult to keep abreast of the advances in fire management research and technology. A guide for using fire retardant chemicals in ground tankers provides fire managers in the South with current basics on storing, mixing, and applying retardants and encourages their on-the-ground trial and use. Fire managers everywhere should find this guide useful, both as a general reference and as a how-to-do-it booklet. (704)

174. For reasons of economy, it may be necessary to close one or several fire-weather stations in a protection area. Since it is logical to close those stations that will have the least impact on the ability of the fire manager to assess overall fire danger, it is desirable to know if there is duplication in monitoring fire climate, and to what degree. A method is proposed for determining this duplication based on an analysis of six elements of fire climate. Stations are grouped on the basis of similarity of sequences of these fire climate elements over the fire season. Such information, used in conjunction with other considerations, may be useful in streamlining fire weather monitoring networks. (694)

175. Planning fire suppression activities requires good, up-to-date accessible weather data. The National Fire Weather Data library is a collection of daily observations from fire weather stations across the United States. Current data are accumulated on collection tapes, then merged onto library tapes annually. The data library is accessible to all users of the USDA computer in Fort Collins, Colorado. (695)

176. The National Fire Danger Rating System is used nationally for assessing fire danger. Procedures for processing fire danger data utilizing a time-share computer via a remote terminal are presented in non-technical language in a recent guide. Input includes fuels and weather information; output includes narrative messages sent from other users, displays of observed and forecasted weather, and fire danger indexes. Observed fuels and weather data are automatically checked for errors and archived. The guide should be indispensable to users of the system. (700)

177. Application of fire retardant chemicals to forest fires has been hindered by lack of definitive criteria for specifying the amount of retardant needed based on the fuel situation. This study developed a method of determining the maximum useful retardant concentration from a knowledge of the fuel load, the size class distribution of the particles, and the chemical makeup of the fuel. The results have been applied to the nine standard fuel models of the National Fire-Danger Rating System and incorporated into the Operational Guidelines for Retardant Tankers. (707)

178. The National Fire-Danger Rating System (NFDRS) needs to be tied closely to local fuels so fire-danger evaluations can be more specific. Fuel models were developed to provide the



data needed in mathematical fire behavior modeling of the spread and energy release components of the NFDRS. The fuel models quantitatively describe those physical and chemical properties of fuel elements and fuel beds that govern flammability. Nine models currently describe broad vegetative types for rating fire danger and can be refined to give greater coverage and incorporate dynamic features such as seasonal variations in fuel properties. More skillful interpretation and application of the information provided by the NFDRS will result. (692)

179. To obtain maximum efficiency of aerially delivered fire retardant, fire control personnel must know and understand the performance of the delivery systems they are using. A method for determining air tanker performance through static testing and a basic format for user guides has been developed to allow more flexible and efficient use of air tankers. The performance guides provide fire management a means for evaluating air tanker operations, comparing different tankers, and assessing the value of specific drops. (708,696)

180. Use of the Canadair CL-215 air tanker by fire suppression agencies has been proposed. Using data collected in drop tests, mathematical models for several retardants and load sizes were developed for predicting the effects of drop height on ground distribution. Retardant drop efficiency and safety can be improved by the use of gum-thickened retardants. This information will be valuable to fire suppression agencies in deciding upon use of the CL-215. (697)

181. Although the term "fire management" is increasingly used today, its origin and meaning remain unclear. A perspective and definition of the term is offered in a recent article in an effort to improve communication and understanding. (690)

182. The basic knowledge to return fire to wilderness is available, but the land manager must proceed very carefully. A study in the Selway-Bitterroot Wilderness Area of Idaho has helped develop procedures for allowing fires to play a more natural role in wilderness. Such wilderness-oriented research can assist forest managers inside and outside wilderness areas. (724)

#### Forest fire science

183. Basic knowledge of fire behavior concepts and the ability to apply these concepts to wildland fire problems should be a part of the skills of all fire control personnel. This publication describes the characteristics of heat that are basic to the understanding of heat transfer in wildland fire. This understanding will enable fire control personnel to do their job more effectively and more safely. (714)

184. Fire managers lack adequate knowledge of the behavior of large fires including mass fires and conflagrations. In a series of experimental free-burning fires, the rate of rise of the convection column depended upon the atmospheric lapse rate in the lower 1000 meters. For the fuel used in these tests—a mixture of Pinyon pine and Utah juniper—the size of a mass fire was defined as  $27 \pm 2$  hectares. These data contribute to the development of theoretical mass fire models. (718)

185. Temperature, wind velocity and direction can vary drastically before, during, and after wild or prescribed fires. A data-recording system based on the logarithmic character of semiconductors has been developed for observing turbulent fluctuations from the mean in ratio form. The system combines a recorder, discriminator, amplifier, thermocouple, and anemometer. It has been satisfactorily field tested under severe ambient and fire

conditions, providing useful fire research data. This system also can be used to record and determine mixing ratios in turbulent areas, providing information needed for air-quality studies. (717)

186. The pocosin shrubs of the eastern North Carolina organic soils area become a severe fire hazard during low points in their annual moisture cycle. Observation of seasonal variation in moisture content of six species of shrubs over two growing seasons revealed an annual pattern of variation for each species. North-south location and proximity to the seacoast had a strong influence on the timing of the annual cycles, and early spring, just before growth began, was the time of lowest moisture content. These results can aid fire suppression forces in preparing for expected severe fire situations. (713)

187. Field experiments of prescribed burning often require measurement of smoke plume volume flow. A method of simultaneous motion picture photography was developed and tested using triangulation from two camera positions. Measurement of coordinate data was made using two stop-frame film projectors mounted beneath a frosted glass viewing table. This inexpensive and accurate method appears adequate for most applications on field experiments of prescribed burning. (719)

188. Prediction of fire danger by the National Fire Danger Rating (NFDR) System requires precise knowledge of moisture content of fuels which, in turn, demands knowledge of the relationship between environmental parameters and the transport of water liquid and vapor into the fuels. Two models have been developed—one for conifer forest litter and duff and one for heavy forest fuels. These models facilitate the estimation of moisture content and, therefore, can be used by the NFDR System. (715,716)

189. In gathering data on fuel loadings, size class distributions, and fuel bed depths for purposes of assessing potential fire behavior, disparate fuel communities frequently are sampled and the data are intermingled. An algorithm has been developed which permits automated partitioning of such data into groups of samples which have similar fuel bed depths. Copies of the computer program are available; use of this method will improve predictions of fire behavior. (711)

190. Proper management of lodgepole pine requires full awareness of the biological effects of fire. The accumulation of ground fuels and related fire intensity potential seems to follow two consistencies: (1) Fuel quantities and fire potential become predictably high as stands reach overmaturity; and (2) fuel quantities and fire potential in young and immature stands cannot be predicted from age alone. A summary paper provides a clearer understanding of the intricate relationships between fuel, fire, and lodgepole pine and will aid fire management in this type. (723,727)

191. Ignition temperatures of fine forest fuels must be known if the rate of fire spread is to be accurately predicted. Spontaneous and pilot ignition tests on the needles of ponderosa pine (*Pinus ponderosa* Laws.) showed that piloted ignition occurred at lower flux intensities and in less time than did spontaneous ignition. A significant difference in delay time to ignition was found for sample moisture contents above 7.7 percent. This information is useful input for rate-of-spread models. (721)

192. The type and extent of land uses and management on municipal watersheds are interrelated with water supply problems. A survey of land uses permitted in municipal watersheds

in the eastern United States was summarized. The survey determined the nature of land-management problems and information, research, and practices needed to improve water supplies from municipal watersheds. This information was needed to formulate research and management programs for eastern watersheds. (66,67)

## IMPROVING INSECT AND DISEASE CONTROL

### Detection and evaluation

193. Wood deterioration in single-family frame houses along the Gulf Coast is extensive and costly for homeowners. A recent survey of homeowners revealed that moisture/decay damage to such houses has been more frequent than termite damage in recent years. Definition of problems occurring in these houses has provided performance aids for building inspectors, architects, and agencies preparing national building codes, and it has indicated need for changes in building designs to reduce damage. (532,533)

194. Cottonwood is damaged by a number of insects and diseases. A recent publication with numerous illustrations describes 10 important insects and eight important diseases of cottonwood. This information will aid foresters and land managers in recognizing major insects and diseases and in selecting means to reduce the damage they cause. (539)

195. Sycamores in some commercial plantings in the South have been killed by diseases; however, the extent of this mortality was unknown. A recent survey revealed that losses averaged less than 5 percent in 26 plantations. This information has prompted forest industries to renew or increase the planting of sycamore. (535)

196. To improve habitats for migrating waterfowl, southern forest landowners from the Mississippi to the Atlantic flyway are increasingly building green tree reservoirs which involve temporary impounding of water. The effects temporary impoundments have on mycorrhizae and other soil microflora in southern hardwoods were evaluated; mycorrhizal species were not eliminated but populations were reduced. No damage to trees was detected. This information can be used by foresters to insure landowners that green-tree reservoirs are not likely to reduce timber production. (534)

197. Fusiform rust is recognized as the most damaging disease of forest trees in the South, but little information has been published relating incidence rates to financial impact of the disease. Data from the forest survey have been expanded to estimate financial impact of fusiform rust southwide. This information will be of value to forest managers in the South. (541)

198. Aerial photography can be used to detect, evaluate, and follow tree disease progression; however, this method is useful only with certain types of diseases. Diseases for which this method has been effectively used have been listed and discussion presented on the newer possibilities of large-scale detection of tree diseases by remote sensing techniques. (537)

199. Better methods are needed for detection of decay in tree roots. The pattern of electrical resistance measurements was used to detect decay associated with *Fomes annosus* in red pine.

The method shows great promise for accurate detection of root decays in trees. (542)

200. In trees with high-unit values, the ability to detect defect within the bole is very important. Tests on black walnut demonstrated that discolored and decayed wood in living trees could be detected using a pulsed electric current. Further refinement and application of this technique will improve management and utilization of this valuable species. (538)

201. The spruce budworm represents a potential threat to nurseries and shelterbelts of the Northern Plains, and a better system is needed to survey for its presence. Traps baited with the pheromone *trans*-11-tetradecenal were placed in 13 shelterbelt and nursery plantings in North Dakota. Moths were captured at 12 of the 13 locations. The sex attractant may prove very useful in (a) detecting populations of this insect pest in nurseries, shelterbelts, and similar plantings in the northern plains and (b) preventing spread of the budworm with movement of infested nursery stock. (372)

202. More effective sampling methods are needed to evaluate the spring cankerworm, a severe defoliator of Siberian elm in the northern Great Plains shelterbelts. Individual trees were sprayed with a pyrethrum insecticide applied by a backpack mist blower, a rapid, nondestructive technique that provides a whole-tree count of cankerworm larvae. This efficient sampling technique has no adverse environmental effects and is applicable for sampling a variety of insects on most trees under intensive culture. (371)

203. Trees and shrubs are valuable components of urban areas on the Great Plains, yet, homeowners often have no knowledge of how to obtain reliable advice on identifying damaging insects or how to control them. This report summarizes basic requirements for proper collection, preservation, and shipment by homeowners for obtaining identifications from their State extension entomologists. A reference table also lists 184 typical or prevalent insects associated with 52 trees and shrubs found in North and South Dakota. With these guidelines, homeowners can make the best use of entomological services available to them, and assist entomologists in becoming aware of local insect problems. (370)

204. The European pine sawfly damages Scotch and red pine plantations, and we need improved sampling methods to improve surveys and damage prediction for this pest. The egg clusters are reliable for sampling population levels, and the distribution patterns of egg clusters are useful in devising sampling schemes. This sawfly has a strong edge effect so that twice as many eggs are found on edge rows and around openings. Eggs were distributed in an overdispersed manner with an index of 1.49 by Taylor's Power Law. We now have a practical sampling method for assessing the numbers and distribution of sawfly eggs in plantations, and this information, in turn, will improve our pest management decisionmaking process. (375)

205. The pine root collar weevil, a pest of red pine plantations, is difficult to sample because of its cryptic habits. Larvae are the most reliable sampling units, but the trees must be sacrificed in sampling because the larvae feed inside the tissues. Egg sampling also yields reasonable population parameters, however, and 93 percent of the eggs can be recovered in the outer bark and soil within 3 cm of the root collar. Distribution of eggs within plantations revealed an overdispersion index of 1.25 (Taylor's Power Law) which indicates they are not strongly aggregated.



With this information, we can now develop a practical egg sampling method that can be used to assess weevil populations and predict potential weevil damage to red pine plantations. (374)

206. Although the white pine weevil is a major pest of coniferous trees in the northeastern United States, we lack sufficient understanding of its biology and population dynamics to develop satisfactory methods of minimizing its damage. A key factor in any control program is a rapid, accurate sampling technique to estimate pest populations. A nondestructive photographic technique for estimating egg density correlates well with the standard time-consuming and destructive technique involving microscopic examination and/or dissection of individual leaders. At least on leaders with low needle density, we now have a rapid, nondestructive method of sampling eggs and thereby projecting adult populations. (378)

207. We need to know the seasonal flight periods of moths attacking seed orchards before we can effectively apply insecticidal controls. Light traps were used to trap and sample species of seed- and cone-infesting moths. With this information, the emergence periods, generations per year, and relative abundance of species were determined. Seed orchard managers can now schedule effective applications of insecticides to control the major seed- and cone-infesting moths. (376,377)

208. Identifying damaging insects and developing methods to evaluate impacts of insect activity are major problems in southern pine seed orchards. Major pest species have now been associated with particular geographic locations, and host age, and seed source. An illustrated key to the identity of a group of cone midges has been devised. Improved sampling methods are being developed for five pine species in seven southern States to enhance our capability to evaluate the efficacy of insect control measures. This information will substantially improve the ability of seed orchard managers to evaluate and employ a number of management strategies to minimize insect losses in seed orchards. (364,365,366,369)

209. More information is needed on the identification of insect pests and their damage in southern pine cone and seed orchards. Keys are now available to identify specific insect pests such as seed worms, flower thrips, seed bugs, and midges. Seed and cone losses directly attributable to insects with and without control attempts have been documented. We now have the basic information necessary to determine research priorities, damage assessments, and control strategies for seed- and cone-damaging insects. (358,359,362,363)

210. Thousands of acres of ohia and ohia-koa rain forests on the island of Hawaii are being decimated by some undetermined factor. Interpretation of aerial photographs taken from 1954 to 1972 shows a drastic decrease in the acreage of healthy forests and a manyfold increase in acreage of forests with severe decline symptoms. This information regarding location, extent, and rate of spread of the decline will help guide management of these important forests. (540)

211. Insects can reduce growth and impair the form of black walnut trees, particularly those trees 3 to 8 years old and being managed for future timber production. In 1974, 62 insect species were found feeding on black walnut trees in Missouri. Bud and shoot insects, which cause loss of terminal dominance, are the most destructive and important. Preventive and corrective measures are needed to reduce the damage. (367)

212. Some measure of the damage caused by tip moths would be useful in selecting pines for afforesting the sandhills. Plantings of loblolly, shortleaf, and Choctawhatchee sand pine chemically treated annually to prevent tip moth damage were compared with untreated plantings at age 10 years. Untreated plantings averaged shorter and smaller in diameter than treated plantings. Differences between plantings were greatest for loblolly and least for sand pine. Untreated sand pines were taller and larger than treated loblolly and shortleaf pines. Results clearly recommend Choctawhatchee sand pine as a likely choice for afforesting sandhill land within its projected range. (361)

### Biology and understanding

213. Chromatographic identification and quantification of plant sugars are often erroneous because of an inability to isolate constituent sugars on chromatographic media. By testing different combinations of solvents and media, thin-layer-chromatography techniques were developed which permit accurate identification and reproducible quantification of sugars in plant extracts. These techniques will be useful to scientists studying physiological changes in plants, particularly changes in sugars caused by disease and insect attack. (585)

214. Information on changes in kinds and quantities of sugars in woody plant tissues when infected by obligate parasites, like the white pine blister rust fungus, is very limited. No qualitative changes in sugars were found between *Pinus monticola* bark infected and noninfected with this fungus; however, there were significantly less glucose, sucrose, raffinose, and total sugars in infected bark tissues. This information will be of value to scientists investigating host-parasite relationships. (632)

215. Host-pathogen interactions at the host cell wall and hyphal cell wall interface are unknown for *Pinus monticola* and the white pine blister rust fungus, *Cronartium ribicola*. Observations of infected bark tissues with light and electron microscopes revealed that hyphae of this fungus are firmly affixed to pine cell walls and covered with a layer of an electron dense, extracellular, gel-like material. Strands of this gel-like material may connect several rust hyphae not otherwise in contact and may bridge spaces between pine cells and unaffixed hyphal cells. Host-parasite interactions are shown for the first time to involve a gel-like material that appears to have an adhesive function. This information adds to our basic knowledge of host-parasite relationships and will benefit scientists investigating such relationships. (633)

216. Investigations to develop genetic resistance to the white pine blister rust fungus in *Pinus monticola* would be simplified by the existence of markers of specific host-parasite combinations. Two kinds of needle spots, red and yellow, were found 9 months after inoculation of nursery grown seedlings with field-run *Cronartium ribicola* inoculum. An analysis of needle-spot types and frequencies indicated that the field-run inoculum was composed of at least two races and that the pine seedlings exhibited differential resistance to those races. The real significance of these findings resides in the possibility of using the races, if they exist, as markers in many kinds of genetic studies of *C. ribicola* and its hosts. (588)

217. A mechanism of resistance to *Cronartium ribicola*, not previously observed in white pines, was found in *Pinus armandii* needles infected by this rust fungus. This mechanism is a hypersensitive reaction which we now can recognize, thus we



can probably find it in *Pinus monticola* and therefore increase its frequency and importance in this species. (568)

218. Knowledge of the extent of pathogenic variation in *Cronartium fusiforme* has been very meager although such information is basic to breeding trees for resistance to this rust fungus. To determine the extent of pathogenic variation in *C. fusiforme*, several slash pine families were exposed to inocula from diverse locations in the South. Although two families were resistant to inocula from five States, most families responded variably to inocula from widely separated locations as well as from individual rust galls within locations. These findings demonstrate much genetic diversity in both the fungus and host populations. The concepts developed will lead to greater efficiency and reliability in resistance breeding programs. (551,624)

219. The lack of an efficient method for inoculating pines with *Scirrhia acicola* has hindered research on the brown spot needle blight disease of longleaf pine. Conditions of light, high humidity, and temperature which favor infection of inoculated seedlings were determined. Thus a new inoculation technique has been developed which can be used to screen pines for resistance to the brown spot fungus. (572)

220. The ability of some decay fungi to attack wood is influenced by light, but it was not known whether light affected the specific assay organisms used in standardized tests of efficacy of wood preservatives against fungi or in tests of wood resistance to decay-fungi. Specific assay organisms that are affected by variations in wave length were distinguished from those that are not. This knowledge can be used to improve the reliability of standard laboratory soil-block wood decay tests. (550)

221. *Endothia gyrosa* causes a canker disease on several species of deciduous trees. Recent studies in the Southern United States indicate this fungus can cause serious cankering on *Liquidambar formosana* and suggests the possibility of an epidemic in Asia reciprocal to chestnut blight in the U.S. Care should be taken to assure that this strain of the pathogen is not introduced into the range of *L. formosana* in Asia. (622)

222. Black stain root disease causes considerable mortality to pines, true fir, and Douglas-fir in Western North America. Information on hosts, distribution, symptoms, disease cycle, damage, and control has been presented in leaflet form. This information will be of value to those interested in reducing damage caused by this disease. (621)

223. True firs in the Western United States can be severely damaged by the canker fungus, *Cytospora abietis*. The biology, symptoms, and damage caused by this fungus have been presented in leaflet form along with suggestions for control. This information will be of value to those who are interested in reducing the damage caused by this fungus. (604)

224. Littleleaf disease of shortleaf and loblolly pines has been attributed to *Phytophthora cinnamomi* on severely eroded, clay sites; however, other root infecting fungi may be involved. Close association of *Pythium* species with *Phytophthora cinnamomi* on sites with littleleaf diseased trees was shown for the first time. This information will be of value of pathologists who are seeking to more fully understand this disease so that losses may be reduced. (599)

225. Any possible role of mycorrhizae as biological deterrents to feeder root diseases of plants has been unknown. Most work has shown that ectomycorrhizae function not only as mechanical

barriers to infection by pathogenic fungi but also as chemical barriers. Many ectomycorrhizal fungi have been found to produce antibiotics ideally located in mycorrhizae to deter infection by pathogens. Further studies will be needed to fully elucidate the role of mycorrhizae in limiting root diseases. (586)

226. Plant-parasitic nematodes have been associated with shortleaf pine exhibiting symptoms of littleleaf disease; but information on which nematodes parasitized feeder roots was unknown. In a greenhouse study, two nematode species, *Hoplolaimus galeatus* and *Meloidodera floridensis*, parasitized pine seedling roots and caused measurable root damage; thus these nematodes must be classified as pathogens of shortleaf pine. (603)

227. The Peruvian Government and other groups are interested in the potential pine afforestation of the grass plains of the high Andes in Peru. Since pine need ectomycorrhizae to survive and grow normally, a mycorrhizal survey was made on the scattered planted *Pinus* and *Eucalyptus* in the Andes of Peru. Only a few ectomycorrhizal fungi were observed, which suggests that pure culture introduction of specific mycorrhizal fungi may be desirable. Since Mexican pines are the desired pine species for the Andes, a mycorrhizal synthesis experiment was conducted with them: *Pisolithus*, *Thelephora*, and *Cenococcum* formed beneficial ectomycorrhizae on them and, therefore, are potentially useful in pine afforestation in the Andes. (587)

228. Spread of *Poria weirii* in stands established in cutover infested sites might be reduced by interplanting species resistant to this fungus. Red alder is a promising candidate for interplanting or crop rotation. Cubes of Douglas-fir wood decayed by *P. weirii* were buried for 12 months in paired plots in red alder soils and in conifer soils; however, survival of the fungus did not differ in the two soils. (593)

229. Information on rate of spread of the root disease fungus, *Poria weirii*, in the Pacific Northwest is needed to improve timber management and recreation decisions. By measuring 10 centers on 1946 aerial photographs and again on 1972 photos, progress of the disease in a given direction was estimated. Thus, in mixed, high-elevation forests of the Oregon Cascade Mountains, foresters can now base their management decisions on projected root disease losses. (592)

230. *Poria weirii* normally survives for many years in buried wood, causing reinfection of stands developing on infested sites. When urea was incorporated in soil around buried cubes colonized by the fungus or broadcast on the soil surface, survival was reduced from 31 percent to 0 and from 48 to 2 percent, respectively. If urea can similarly reduce survival of the fungus in colonized roots of stumps and dead trees, it could provide effective control of *P. weirii* on harvested forest lands. (590)

231. The mechanism of reducing *P. weirii* survival in buried wood by application of a given level of nitrogen is not known. Alder stem sections colonized by *P. weirii* were buried in soil and incubated at 15°C. over a period of 32 weeks. Fungus survival lessened with time. The larger the N application, the greater was its effect on survival. Populations of *Trichoderma* were associated with decline in survival. Stimulation of *Trichoderma* by levels of urea used here might also be effectively used to reduce survival of *P. weirii* in nature. (591)

232. *Phellinus (Poria) weirii*, occurring over a wide variety of forest types and sites, varies considerably in appearance and in physiological characteristics. Growth of high and low elevation

isolates was not different between 5° and 30°C. nor was survival between -20°C. and 34°C. Thus, much of our knowledge of low-elevation *P. weirii* accumulated over the past 30 years probably applies to high-elevation *P. weirii* as well. (594)

233. Proposed methods for controlling *Phellinus* (*Poria*) *weirii* root rot cannot be quickly assessed in field studies because the fungus cannot be isolated from soil or root surfaces. Thus, its response to a control treatment can be evaluated only indirectly and often only after many years. Now the nutritional requirements of this fungus have been determined, and it can be grown more easily in culture. This knowledge will be helpful in improving the efficiency of research on control methods. (583)

234. Red alder has potential for biological control of *Phellinus* (*Poria*) *weirii* root rot in the Douglas-fir region, since it resists the disease and changes soil properties to the detriment of the fungus. However, young (10-17-year-old) Douglas-fir plantations which contain naturally regenerated alders of the same age have as high an incidence of the root rot as plantations where alders are absent. Clearly, alder needs more lead time to diminish the pathogen's infective population. (562)

235. Research on mycorrhizae that are vital to survival and growth of trees has been impeded by an inadequate system for classifying and identifying the fungi involved. Significant progress in classifying these important fungi is represented by recent monographs of one entire family and three additional genera of hypogeous, mycorrhizal fungi. Numerous related classification questions have been resolved, so that these fungi can now be incorporated into research on mycorrhizae. This is a vital step towards developing methods to manage mycorrhizae for increasing tree survival and yield. (625,626,627,628,629,630,631)

236. Insects that feed on fungi are primary dispersal agents for many beneficial and pathogenic species of fungi. A bibliography listing nearly 300 articles relating to this subject has been published. From information in these articles, listings have been made of beetles associated with fruiting bodies of mycorrhizal fungi. This information will be helpful to those engaged in insect-fungus related research. (552,553)

237. Some tree species do not absorb nitrate nitrogen effectively; however, certain mycorrhizal fungi symbiotic with tree roots can reduce nitrates to forms readily absorbed. A recent experiment indicated that two vesicular-arbuscular mycorrhizal fungi can reduce nitrates. Thus, it is likely that trees having these fungi associated with their roots could effectively compete for nitrates in soil even though they could not absorb nitrates. (566)

238. The taxonomy of mycorrhizal fungi is difficult for most mycologists. The presence of an active acid phosphatase in cultures of six ectomycorrhizal fungi was detected after incubation with Disodium p-nitrophenyl phosphate. In a subsequent starch gel electrophoretic analysis, three of these species produced a fast intense reaction in the developing solution and the other three reacted slowly with a weak, blurred spot. Fungal taxonomists now have another factor to use in differentiating between these species. (567)

239. Little is known about the kinds and extent of injury caused by nematodes in Pacific Northwestern forests. A nematode species previously reported to infest mycorrhizae of Douglas-fir has been discovered on mycorrhizae of western hemlock and Sitka spruce. With this information, forest pathologists will

be better able to keep watch for damage caused by this nematode. (635)

240. Before we can manage populations of gypsy moths, we must understand the mechanisms by which innocuous populations dramatically increase to damaging levels. In low populations, egg-mass density was 10 times higher along the forest edge than within the forest. Half the egg masses found at low densities were deposited on man-made objects—litter. Thus, littering the forest edge could contribute to the likelihood of future gypsy moth outbreaks. (395)

241. A number of tree diseases previously thought to be caused by viruses now are known to be caused by mycoplasmas. A recent review of these diseases lists mycoplasma-associated diseases of trees and discusses symptoms. This information will be helpful in disease identification. (634)

242. A serious problem of the eastern deciduous forests in recent years has been the dieback and decline diseases of important tree species. Both drought and defoliation have been associated with these diseases. The combined effects of drought and defoliation resulted in lower levels of starch in roots of black oak seedlings than either drought or defoliation alone. This information indicates that stress prior to or in combination with defoliation could result in greater tree damage because of greater depletion of food (starch) reserves. This information will be useful to pathologists investigating dieback and decline diseases. (602)

243. Knowledge of the location of food reserves (starch) in roots of deciduous trees is needed for investigations of dieback and decline diseases in eastern forests. The major portion of starch in roots of sugar maple was found to be stored in the xylem and ray parenchyma cells. This information will be useful to research foresters and others engaged in disease research. (600)

244. Survival mechanisms in trees subjected to defoliation are poorly understood. From a study of the magnitude of photosynthesis in *Quercus velutina* under various conditions, it is concluded that photosynthesis in twig bark may be important in enabling a tree to survive loss of foliage. Plant physiologists and others will use this information as a basis for further investigations. (601)

245. Surveys of previously affected beech stands indicate that both agents of beech bark disease (the scale, *Cryptococcus fagi*, and the fungus, *Nectria coccinea* var. *faginata*) are now endemic. Regeneration (via root sprouts) of killed beech has created highly susceptible beech thickets, thus setting the stage for a recurrence of heavy beech mortality over wide areas. (571)

246. Better methods are needed for non-destructive determination of physiological processes of disease that precede symptom expression. One method was developed as a result of testing the hypothesis that disease resistance is related to vigor, and vigor is related to cambial ion concentration. The technique involves measuring cambial electrical resistance. Researchers will find this technique useful in further studies involving disease development in trees. (616)

247. It is not clear what happens as root decay spreads from the roots to the trunk of a tree. Dissections and studies of red pine infected with *Fomes annosus* showed that the decay was compartmentalized in the trunk. The diameter of the trunk at the time the fungus moved from the roots to the trunk was the diameter of the trunk decay column. An understanding of com-



partmentalization of root decay in the trunk is essential to understanding the development of the root problem. (608)

248. The factors that initiate heartwood formation in trees are poorly understood. Results of research indicate that wounds stalled the formation of heartwood in white oaks in Maine and Missouri. This information will be valuable to those interested in high value heartwood in many species of trees. (589)

249. Better methods for controlling tree decay depend on a better understanding of it. An expanded concept of decay has been developed which includes host response to wounding and successions of microorganisms. Compartmentalization of decay is an important part of host response mechanisms. Trees repair injured tissues by compartmentalizing them. An understanding of compartmentalization will help us develop more effective methods for controlling decay. (609,610)

250. Great confusion still exists regarding differences between heartwood and discolored wood in trees. Investigations have shown that discolored wood results from injuries, while heartwood results from normal aging processes. Knowing the difference between these two processes can help the tree manager make decisions on the value of wood in trees. This information should be of benefit to all tree managers, especially those interested in high-quality wood products. (611,612)

251. Wounds are the number one problem of city trees. These wounds start the processes that lead to decay. Information on wounds and the processes leading to decay have been summarized. Through a greater awareness of these processes, better methods for detection and prevention of decay can be accomplished. The fact that commonly-used wound dressings do not stop tree decay is of particular interest. (613,614,617)

252. The beech bark disease is well established in the Eastern United States and is spreading. A detailed account of this disease has been prepared for use by tree managers in developing more effective plans for combating the disease. (615,618)

253. Resistant clones of aspen provide the most likely method of reducing losses to *Hypoxyylon* canker, but knowledge of the variability present in the pathogen must be obtained to help guide development of screening procedures for selecting resistant aspens. *Hypoxyylon mammatum* was found to possess a large amount of variability in nature; thus screening for resistance must be done with a large number of biotypes of the pathogen obtained throughout the region where candidate clones will be used. (547)

254. Land managers in the North Central States are concerned with *Hypoxyylon* canker of aspen, and often request details for identifying the disease and guidelines for managing the aspen resource to minimize losses. A brochure has been prepared which illustrates in color photos and text the symptoms for identifying *Hypoxyylon* canker of aspen and gives management guidelines for reducing the impact of this disease. (606)

255. Hypoxyylon canker is a serious disease of quaking aspen and is present throughout most of the range of aspen. Investigations of this disease have been hampered because of a lack of information on how infection occurs under natural conditions. In recent investigations, four-fold more peroxidase was present around newly infected wounds than around noninfected wounds. More importantly, an inhibition of the wound-healing response in the bark is one of the first events that occurs when aspen becomes infected. A toxin has been shown to be responsible for the inhibition of healing. The results suggest that infection occurs

after a bit of cankered host tissue containing toxin and mycelium is placed in a wound by an as yet unknown vector. This information will be extremely useful to pathologists investigating this disease. (605,607)

256. Hypovirulent forms of the chestnut blight fungus, which are dominant over the pathogenic wild types, have appeared in Europe. The hypovirulent character can be transmitted to pathogenic strains in such fashion as to suggest that a virus might be associated with this effect. Tests of 11 hypovirulent and 23 virulent isolates indicated that dsRNA was present in both. Further tests will be done with other genera of fungi to learn if dsRNA may be a more common cellular constituent than had been previously thought. (573)

257. Research on enzymology of forest trees is often hampered because enzymes in extracts from trees lose their activity rapidly after extraction. Tests were made to determine if removal or inactivation of phenolics present in extracts of trees would preserve enzyme (dehydrogenase) activity. Combined phenolic removal and inactivation with sulfhydryl reagents were more effective than inactivation alone. Combined sulfhydryl containing reagents and oxidized nucleotide coenzymes effectively preserved enzyme activity. These results give plant scientists a means of measuring the activities of dehydrogenases present in woody species where previously activity was lost before measurement could be made. (558,559,560)

258. Loss of enzyme activity in crude extracts from trees hinders physiological investigations. To determine if enzyme activity loss is due to proteases in crude extracts, a method was developed to measure proteolysis in crude extracts because existing methods are not sensitive enough. The method developed was based on estimating protease activity with radioactive protein labeled with <sup>125</sup> Iodine. This method was found to be an order of magnitude more sensitive than published methods. The method can be used to measure the activity of specific protease enzymes in the presence of other protease enzymes and is not affected by the presence of phenolics found in abundance in extracts from woody plants. (561)

259. *Scleroderris* canker, caused by *Scleroderris lagerbergii*, and shoot blight, caused by *Sirococcus strobilinus*, continue to cause serious losses in pine plantations in the Northern United States. The two diseases have been described and the life cycles of the fungi responsible for the diseases have been presented in a recent publication. Recommended control procedures are discussed for plantation and nursery conditions; these can be used anywhere these diseases are found. (619)

260. Lophodermium needle cast has recently become one of the most damaging diseases of pines in nurseries and Christmas tree plantations in the United States and Canada. The life cycle of the causal fungus has been determined, which has resulted in determining the proper timing of fungicidal and cultural controls. Managers of nurseries and Christmas tree plantations will be particularly interested in this information, since by following the developed control procedures, they can again produce healthy trees. (595,596,597,598,620)

261. A reliable rearing method is needed to provide a continuous supply of pales weevils for conducting research on this serious pest of pine reproduction in the eastern United States. The method that has been developed fulfills the requirement of a continuous supply of insects by producing a ratio of new to parent weevils of over 50:1. The success of this rearing method will



permit continuous research on biological and insecticidal control of this important insect. (451)

262. Procedures are needed to develop white pine blister rust resistance in western white pine. Collections of seed from surviving stands that have sustained high mortality (80-90 percent) due to infection in the Northern Rocky Mountains produce seedlings that are 19.8 percent healthy—an 18 percent increase in resistance over the native population prior to introduction of the disease. Use of this breeding approach will enable forest managers to develop resistance in western white pine by using natural regeneration of surviving trees in areas of high blister rust mortality. (569)

263. An understanding of pales weevil population fluctuations could help avoid losses caused by this major pest of conifer reproduction in the Eastern United States. The effects of temperature, relative humidity, and water submersion on eggs were studied. Temperatures below 24°C. prolonged development; high relative humidities hastened development. Eggs survived submersion in water for 3 days with no adverse effects. Additional studies are needed to properly assess the value of weather patterns for predicting pales weevil populations. (452)

264. Defoliators such as western spruce budworm cause serious damage to our western forests, and silvicultural methods are urgently needed to minimize such damage. Western spruce budworm damage may differ by tree species, which, in turn, could influence management practices. Recent studies showed larval densities were similar on grand fir and Douglas-fir, but grand fir suffered more damage in a given period of time. These findings could influence stand management in the mixed conifer type of eastern Oregon and Washington, since a greater abundance of grand fir would increase susceptibility of the forest to damage by the western spruce budworm. (396)

265. The impact of insect damage on recreational values can be an important factor in an economic analysis of damage, and guidelines are needed to permit such analyses. Tree mortality and top-kill caused by Douglas-fir tussock moth were evaluated on a campground in California in 1970. Cleanup costs of dead and hazardous trees amounted to \$23.75 per camp unit; when an esthetic value was assigned to trees, the costs increased to \$126.88 per camp unit. Clearly, the esthetic value of campground trees must be considered in determining suppression programs against pests in such areas. (458)

266. Knowledge of the reproductive behavior of the Douglas-fir tussock moth is important for timing egg mass collections and developing a sampling technique using sex attractants or pheromones. Observations were made of adult flight, mating, and oviposition in eastern Oregon. Male flight began at 1000 (PST), increased to a peak at about 1700, and concluded at 1930. This coincided with peak mating activity, and the wingless females oviposited immediately following conclusion of mating. Sticky traps baited with virgin females were very effective in attracting male moths, indicating the feasibility of using the pheromone as a detection and sampling device. (457)

267. Understanding how different hosts influence Douglas-fir tussock moths is necessary to understanding the moths' population fluctuations and epidemics. High density field populations were simulated in the laboratory by forcing larvae to feed on old-growth foliage of Douglas-fir, grand fir, and subalpine fir. This created a stress factor that resulted in increased frass production, development time, and number of instars, in addition to

decreasing head capsule size and egg production. Number of eggs produced was greater from foliage obtained from the top of the crown. Understanding these host effects significantly increases our understanding of tussock moth population dynamics and therefore our capability to develop appropriate management strategies to minimize tussock moth damage. (385,386)

268. Christmas tree growers often need to know if the needles damaged by a pest one year would be visible the next year. A life-table for Douglas-fir foliage has been developed showing loss and replacement of needles through time. For example, in a plantation scheduled for cutting in year 10, an insect problem in year 6 on new needles is insignificant since those needles would present only 2 percent of the total by harvest time. With this kind of information, Christmas tree growers are better equipped to make economically sound pest control decisions. (435)

269. Little is known of the adult flight and host selection patterns of the white pine weevil, *Pissodes strobi*, a serious pest of Sitka spruce along the coastlines of Oregon, Washington, and British Columbia. A Forest Service-sponsored study at the University of Washington has shown that most flights occur above 21°C. and the seasonal flight period lasts 7 weeks, peaking during the last 3 weeks of May. The first weevils to fly showed a strong dual preference for leaders on trees not previously infested and for those infested 2 years before. These preferences remained throughout the flight period although at a much diminished level. This basic information significantly increases our understanding of the white pine weevil and increases our capability to minimize its damage. (440)

270. Despite much recent research in insect pathology, no survey of insect and mite virus diseases has been published since 1960. A "Catalog of Virus Diseases" has been prepared that is a condensed summary of a computer-based file of publications on insect and mite viruses. The "Catalog" lists over 600 species of insects and mites, each with one or more of 20 viral diseases or disease groups, for a total of 900 host-virus records. Specific details on virus characteristics can be retrieved from the master file. Use of the "Catalog" will accelerate identification of virus diseases for insect pathologists around the world. (430)

271. Ponderosa pines vary markedly in their resistance to western pine beetles but the factors responsible for this variation are not understood. An inspection of existing data suggests that resistance is strongly affected by resin quantity and quality and by attack density (beetle quantity). Presumably, beetle quality is also important. A formula has been devised describing the role of these factors in establishing resistance of ponderosa pine to the western pine beetle. This formula can assist management in making beetle control decisions and in determining entomological and tree breeding research priorities and programs. (447)

272. Adequate methods have been lacking for predicting white fir mortality caused by the fir engraver and the round-headed fir borer. Weather and associated tree growth were analyzed for potential use in predicting annual average loss of fir sawtimber. Increases in mortality were preceded by 1 to 2 years of decreased radial growth and one or more years of subnormal precipitation. An equation is provided to help forest managers predict these insect-caused losses. (408)

273. Although shrubs are important vegetation components on big game ranges, watersheds, recreation areas, and homesites, we know very little about their associated insects. A man-

ual, the first of its kind, provides information on hosts, range, damage, and biological information on 43 species or groups of insects and one mite. The manual will help range and wildlife specialists, teachers, students, and others with an interest in native shrubs to better understand both the beneficial and detrimental shrub-associated insects. (409)

274. Understanding the mortality factors influencing survival of mountain pine beetle is essential for understanding the fluctuations of its populations and damage. A mix of mortality factors was analyzed by probabilities of death from specific causes and all causes within single life stages and for the generation as a whole. These analyses provide the basis for discussion of known mortality and hypothetical manipulation of mortality factors. Awareness of how mortality factors operate singly and together will permit additional characterization of the population dynamics of the mountain pine beetle, knowledge that should lead to the development of more effective management strategies. (400)

275. Mathematical models describing mountain pine beetle survival and beetle-caused damage to lodgepole pine could be very important in developing effective beetle management strategies. Current research has shown that the greatest beetle survival and emergence occurred in large diameter trees. After most large trees were killed, gallery starts and egg production continued to increase, but larval survival declined and emergence returned to the endemic level. These observations demonstrate the association of beetle dynamics with diameter structure of lodgepole pine stands, and support the theory that epidemics are strongly dependent upon large trees with thick phloem. Such information will assist foresters in delineating areas susceptible to mountain pine beetle. (401)

276. Management of lodgepole pine can be improved by a better understanding of the variety of insects adversely affecting different stages of stand development. Insects infesting seeds and cones do not appear to cause a major impact, but those infesting terminals cause deformed trees of lower value. Defoliating insects slow growth thus delaying harvest time. Bark beetles are the most serious problem, particularly the mountain pine beetle that typically kills most large diameter trees in a stand. This involved understanding of lodgepole pine-related insects and their damage will benefit our research and protection programs for the lodgepole pine resource. (379)

277. Lodgepole pines attacked by mountain pine beetle sometimes "pitch-out" attacks by resin exudation and the question arises whether this may represent tree resistance. One hundred twenty-nine beetle galleries in 32 recently attacked trees were examined to determine incidence of "pitching-out." With one possible exception, galleries containing no females had been abandoned, although pitching-out had not occurred. Low occurrence of males, which probably resulted in low incidence of female fertilization, is believed to be responsible for most gallery abandonment. Further research is needed to determine the extent of gallery abandonment or "pitching-out" on a population basis before we can accurately assess their roles in limiting the mountain pine beetles' attack success. (380)

278. The Western spruce budworm, one of the most widely distributed and destructive forest insects in North America, has been studied since 1922; yet, much information written on this insect lies in scattered, unpublished reports in R-1 and R-4 offices. This information has now been collected, reviewed, consoli-

dated, and published in one technical report. Summary reports such as this are invaluable for planning future research and pest management projects on this pest problem. (426)

279. Preliminary studies on natural enemies of the southwestern pine tip moth indicated that certain lizards played a role in predation that could be significant in the biological control of this pest. Analyses of 86 lizards stomachs indicated that termites are the major food of the eastern fence lizard in late July and August. Four families of insects and ten families of spiders are reported for the first time as lizard prey. Lizard predation on the southwestern pine tip moth is of little value in the biological control of this insect. (454)

280. Ponderosa and lodgepole pines are native hosts of the mountain pine beetle in the Rocky Mountain area, but this insect also damages Scotch pine that is planted as an ornamental. In urban plantings, the mountain pine beetle attacked and damaged Scotch pine 8.5 inches in diameter (DBH) and larger. The Scotch pines were apparently preferred by the beetle over native hosts, since nearby ponderosa pines were not attacked. This finding indicates that Scotch pine may not be a good choice for ornamental plantings in areas where mountain pine beetles are common. (433)

281. Although bird predation is recognized as a major natural mortality factor of many insects, the individual roles of two closely related flycatcher species were thought to be competitive. The western flycatcher displaced the Hammond's to some degree from aspen-conifer habitat, and was the superior competitor in the study area of southern Colorado. Local coexistence was probably temporary and unstable. Thus, even though the two flycatcher species have slightly different habitat preferences, one or the other will be dominant in a given area, a fact that must be considered when studying the mortality factors of specific insects. (384)

282. Spiders may cause significant mortality of forest insect pests including certain bark beetles. Two female lynx spiders were observed feeding on pine engraver beetles on ponderosa pine in Arizona. Another specimen of engraver beetle was found ensnared in the web of a different spider species. These findings will contribute to a better understanding of *Ips pini* population dynamics and eventual control strategies in the Southwest. (425)

283. The ability to determine the sex of insect pupae is important in many studies where freshly emerged adults are needed. Large aspen tortrix pupae can be sexed by the position and configuration of the genital pore. This finding will greatly facilitate large aspen tortrix research that requires freshly emerged adults. (424)

284. Knowledge of the ponderosa pine tip moth's biology and behavior is necessary to develop management strategies. This insect overwinters in cocoons attached to root collars of ponderosa pine; adults emerge, mate, and eggs are laid in April. Eggs hatch in June and larvae pass through five feeding stages in which needles and then shoots are mined. Eggs are deposited on the inner surfaces of needles in upper crowns of small pines. This information will assist in designing more efficient survey methods and control applications. (422)

285. Abnormally developed insects may sometimes be confusing to identify. A female southwestern pine tip moth pupa with an abnormally segmented abdomen was found in the San Juan National Forest in Colorado. Reports of such abnormal speci-



mens are very rare. The descriptions of this finding may help avoid future confusion in the event of similar discoveries. (387)

286. The spruce beetle annually kills 300-500 million board feet of spruce in North America; obviously, better management techniques are needed to minimize its damage. Most outbreaks originate in blowdowns, but cull logs may also be a contributing factor. Overmature trees are usually attacked first, but trees in all diameter classes may be killed. Englemann spruce-subalpine fir stands can be rated for potential spruce beetle outbreaks on the basis of physiographic location, tree diameter, basal area, and percentage of spruce in the canopy. Land managers can now determine stand vulnerability to spruce beetle attack and, in some cases, may be able to avoid severe beetle-caused mortality. (443,444)

287. Although phytophagous insects are common elements of most forest ecosystems and occasionally cause widespread defoliation, we understand very little about their long-term effects on the ecosystem. Usually, the number of insects are inversely related to host plant vigor, and normal defoliation, 5 to 30 percent, seldom impairs annual plant production; in fact, it may accelerate growth. Insects can function as regulators of primary production by culling out weakened plants, thereby making the growth-regulating factors—such as moisture and nutrients—more available to remaining vegetation. Understanding long-term defoliator-host interactions and impacts may significantly modify current pest management schemes in many forest ecosystems. (432)

288. Populations of forest tent caterpillar periodically erupt causing severe defoliation of trembling aspen in the Great Lakes Region, and the factors causing these outbreaks are not well understood. Outbreaks in northern Minnesota during 1964-1971 caused 60+ percent tree mortality on very wet sites, but only negligible mortality at drier locations. Variations in egg densities were due primarily to survival of early-stage larvae and secondarily to survival of late-stage larvae. Mortality of overwintering eggs depended on severity of winter temperatures. These findings enhance our understanding of the epidemiology of outbreak forest tent caterpillar populations and increase our capability to predict their outbreaks. (460)

289. We know very little about the insects that inhabit the pollen-producing strobili of red pine, even though they could be important factors in limiting seed production. In two seed production areas in northern Minnesota, male strobili clusters had an average of 2-9 insects each, each tree hosted about 4 to 10 thousand insects. Many different species were found including some significant pests such as the jack pine budworm, Zimmerman pine moth, and coneworms. All the strobili-inhabiting insects had a negligible impact on the production of pollen. (431)

290. The sweet-fern underwing is a defoliator and potential biological control agent of sweet-fern, which is the alternate host of an important forest pest, the *Saratoga* spittlebug. The underwing, a little studied insect, has one generation per year and is attacked by several species of ichneumonid parasitoids. Its potential as a biological control agent of sweet-fern is doubtful due to consistently low population levels and parasitoid attacks. (459)

291. Better communication is needed among the widely scattered membership of biologists, chemists, and other specialists employed by the 267 member organizations of the International Union of Forestry Research Organizations (IUFRO). To help

achieve this communication, a world directory of forest pathologists and entomologists has been prepared. Scientists are listed by country with their addresses and research interests. Also included are indices for tree genera, pathogen and insect genera, research interests, and scientists' last names. This bibliography will enhance opportunities for every forest entomologist and pathologist to interact with other forest scientists of the international community. (381)

292. Three thousand acres of sugarberry trees were moderately to completely defoliated in Mississippi by larvae subsequently identified as immature forms of the hackberry butterfly. Toward the end of the outbreak, a virus disease and parasitism were discovered in the population. No noticeable defoliator occurred the following year—an indication of natural controls suppressing the outbreak after only 1 year's defoliation. This infestation should be a useful example in evaluating and understanding infestations of the hackberry butterfly in the South. (450)

293. Sap beetles feed and reproduce in sap spots that heal over and form defects in hardwood lumber; however, the beetles' involvement in the cause of this process has never been clearly established. Recent research has demonstrated that insect borers, not sap beetles, are the primary agents in initiating sap spot in oaks although sap beetle feeding possibly enlarges the sap spot and resulting defect. These results will help to correlate insect-caused degrade and loss with the responsible insect which will be useful in determining research priorities. (448)

294. Basic information has been lacking on the biology of the ash borer, a serious pest of green and white ash in North America. A detailed study in Mississippi revealed this insect has one generation per year; adults emerge March-July, and females deposit 400 eggs during the first 2 days. A description of life stages and larval galleries, distribution, hosts, stand conditions, natural enemies, direct control methods, and status of systematics is presented. We can now effectively recognize the ash borer and its damage as well as prescribe natural, cultural, and direct controls—information of considerable importance—to land managers in the South. (449)

295. Improved procedures are needed for rearing the carpenterworm, a serious pest of oaks and other hardwoods in the Eastern United States. An artificial diet was formulated into partially dried cakes and presented to larvae in disposable plastic rearing containers. Almost 60 percent of established carpenterworm larvae survived on this substrate. This diet reduces microbial contamination and frequent handling and provides an acceptable procedure for rearing and maintaining a supply of carpenterworms for research purposes. (429)

296. Mites are known predators of the southern pine beetle and other bark beetles, but identification methods to differentiate mite species has been lacking and this hampers biological control evaluations. Current research has provided a key and other descriptive information to identify the mites preying on the southern pine beetle. Several new species have been described and a number of species have been identified as particularly promising biological control agents. A firm basis has now been established to evaluate the potential of both native and exotic mites as biological control agents of the southern pine beetle. (402,436,437,438,439,445)



297. Before predatory mites can be evaluated as control agents of bark beetles, reliable procedures to identify them by species are needed. The five species of *Histiostoma* associated with the southern pine beetle have been one of the more difficult groups to separate by species. In part, this difficulty reflects the fact that *H. conjuncta* was known only from the phoretic (non-feeding) stage. The recent discovery of the female, male, and immature stages of this species now makes the group easier to identify, allowing biological control workers to test the species for predation on the southern pine beetle. (461)

298. Researchers and land managers have speculated that host tree resistance to southern pine beetles may be lessened by moisture stress which, in turn, may affect the composition of xylem oleoresin. Recent research has indicated that moisture stress decreased the proportion of resin acids relative to monoterpene hydrocarbons in the oleoresin. Changes were more pronounced on poorly drained sites and in trees with deficient root systems. Research must now be continued to relate these changes in oleoresin composition to southern pine beetle susceptibility. (415)

299. Although mycorrhizal fungi form a necessary part of the larval southern pine beetles' diet, we have not previously known their release site in the mycangium. The primary method of inoculation of spores into the gallery is by release along the edge of the presternum with the spores coming from openings in the sternum and/or the anterior thoracic fold. This information is important for other researchers using the scanning electron microscope to demonstrate release of mycangial fungi and to elucidate the biology of these fungi. (382)

300. Mycangial fungi are important associates of the southern pine beetle, and an understanding of their biology and identity are essential to pest management research. The yeast stage of *Sporothrix* sp. (SJB 133) is similar to that of *Sporotrichum schenckii*. The SJB 133 *Sporothrix* differs in several respects, including (1) the cell wall of the yeast-stage had low affinity for electron stains; (2) cells tended to be pyriform; and (3) distinct paramural pockets were observed in SJB 133. SJB 133 produces a phase in the mycangium that provides "Propagules" to be released into the beetle gallery. These results explain how mycangial fungi are related to filamentous forms and how they reproduce before release into the beetle gallery. (412)

301. Information on bark and timber beetles, related microorganisms, and host trees is scattered widely throughout the literature of several disciplines. A recently published bibliography lists 244 abstracted articles published between 1965 and 1974 arranged alphabetically by senior author. This bibliography is a valuable research tool for all scientists interested in scolytid development, symbiotic relationships, and woody host tissue interactions. (383)

302. Insect response to pheromones is highly specific and slight changes in structural chemistry can greatly influence the biological activity upon which control or survey applications may depend. Initial reports of the aggregation pheromone produced by the European elm bark beetle, the principal vector of Dutch elm disease, described nonstereospecific synthesis of the pheromone that yields four isomers. Stereospecific synthesis procedures are needed that will permit particular structural assignments of these isomers. Recent research has discovered the stereochemical assignment for the C-2 and C-4 methyl groups in the four isomers, as determined by chemical and spec-

trometric data. This information is important for determining the relationship between molecular structure and biological activity and, ultimately, for success of survey or control applications. (411)

303. A means to chemically disrupt spermatogenesis of the smaller European elm bark beetle, principal vector of Dutch elm disease, could limit the insect's reproduction and damage capability. Thus, an understanding of reproductive biology is necessary before effective tests can be undertaken. Testicular volume increased rapidly during larval and early pupal stages, reaching a maximum in the pupal stage and declining in the adult. Spermatocytes, spermatids, and spermatozoa were all found in the adult, indicating that spermatogenesis continues into this stage and that adults are susceptible to treatment. This information is of fundamental importance should the control approach of limiting reproduction by disrupting spermatogenesis ever be implemented. (428)

304. Laboratory rearing of forest insects is often essential to insure a continuous supply of uniform research specimens; yet, recent research has demonstrated that rearing red oak borers in continuous light caused them to be sterile. The sterility is thought to have been caused by the destruction of specific vitamins. Successful laboratory culture of the red oak borer requires further study to determine the explanation of this problem and to ascertain other potential problems. (410)

305. The redhumped oakworm is an important pest of oaks in the north central region of the United States, and land managers need easily understood, accurate information about this pest to assist them in making control decisions. A popularized report is now available that describes the oakworm's biology, natural enemies, cyclic habits, and impact of defoliation. This information will assist land managers and other persons in dealing with outbreaks and will inform the public of the pest and its characteristics. (434)

306. Predatory mites can be important agents for biological control of insects, but we need more basic biological information about them before we can assess their value in biological control programs. Recent studies contribute to the knowledge of how photoperiod and temperature can influence induction and duration of diapause (resting stage) of a predatory mite. The importance of alternate prey species during a particular time of year is also emphasized. We now have a better understanding how two very different factors may limit the activity or distribution of a potential natural control agent. (416,417,421)

307. Although biological control is already a significant factor in the natural control of some forest insects, it may be possible to genetically improve the effectiveness of some biological agents. Essential to such programs are clearly-defined attributes of the parasitoid, adequate genetic variability, proper selection procedures, and maintenance of the desired characteristics. Hybridization of geographic strains of parasite species is one approach to accomplish the desired quality improvement. Some promising results in this direction have been obtained with *Apanteles melanoscelus*, a gypsy moth parasite. More work is needed to elaborate this approach, but breeding of parasitoids could significantly improve the effectiveness of biological control of gypsy moth and other pests. (418,419,420)

308. Biological agents are important factors in controlling some forest insects, but improved methods are needed for evaluating the effectiveness of individual parasites. Because parasit-

ism of the variable oak leaf caterpillar by *Diradops bethunei*, a parasitic wasp, causes reduction in head capsule size of the caterpillar hosts, the rate of parasitism can be determined from host head capsule measurements. This technique provides a quick, accurate assessment of the rate of parasitism by this parasite without time-consuming dissections of the caterpillar larvae. (453)

309. The gypsy moth is the most important defoliator of hardwood forests in the Northeastern United States, and better information is needed on its egg mass distribution and population dynamics to facilitate pest management decisions. Recent research has provided information on how to find egg masses and pupae and assess their value in predicting population trends. An interactive model is also provided that relates tree vigor, defoliation, and mortality to egg mass density. Land managers are now better equipped to detect gypsy moth populations, predict damage, and make control decisions. (389,390,392,394,455,456)

310. The gypsy moth is the most important hardwood defoliator in the northeastern United States, and managers, homeowners, and other interested individuals should be able to distinguish the different life stages of this moth and recognize some of its natural enemies. Two publications discuss all aspects of gypsy moth biology, habits, and natural control. The photographs and color drawings are invaluable for essay identifications. The public now has the information to understand some of the complexities of gypsy moth biology and to readily identify this insect and its natural enemies. (391,462)

311. Contrary to the regular oscillations characteristic of gypsy moth populations across much of Europe, populations in North America are characterized by two numerical phases of greatly varying duration. A recent study of populations in an outbreak area and in an innocuous area reached several conclusions relating to egg production, instar survival, and sex ratios. Further studies along similar lines should greatly increase our understanding of gypsy moth population phases which, in turn, should enhance our capability to develop effective pest management systems to minimize gypsy moth damage. (393)

312. Although the pales weevil is the most serious insect pest of pine reproduction in the eastern United States, we lack considerable information about its biology and habits. Recent research has shown that adult weevils do not reproduce in the winter months and that dietary sterols are essential for larval survival and growth. These results indicate that foresters (1) can plant in winter without concern for weevil buildup and (2) that researchers should consider sterol fluctuation in host trees as a possible factor influencing weevil populations. (398,441)

313. We cannot accurately predict population trends of the elm spanworm, an important defoliator of hardwoods in the southeastern United States. A study of leaf quality indicated that adult longevity increased when larvae were fed on hickory instead of oak foliage. Juvenile leaves favored spanworm development more than mature leaves, a fact probably related to a decreasing concentration of major fatty acids with leaf maturation. Leaf sterols varied little throughout the growing season. A more complete understanding of spanworm nutrition could assist in predicting the occurrence and duration of spanworm outbreaks. (399,403)

314. The need for effective insect control agents coupled with environmental safety concerns has encouraged a search for more selective insecticides. These materials can perhaps be synthe-

sized if the chemical requirements of the active surface of the target enzyme can be established. A number of acetylcholinesterase inhibitors were synthesized and tested on insects and other animals. Differences with respect to enzymatic binding, reactivity, and penetration to the site of action were observed. These findings contribute to a better understanding of the toxicological differences between species that may be exploitable for development of selective insecticides. (413)

315. Because of the growing concern to develop environmentally safe pesticides, more specific information on pesticide degradation is needed. Five forest fungi were evaluated for their effectiveness in degrading Aldicarb, an insecticide commonly applied to soil. In decreasing order of effectiveness, the fungi were: *Glocladium catenulatum*, *Penicillium multicolor*, *Cunninghamella elegans*, *Rhizoctonia* sp., and *Trichoderma harzianum*. Apparently, Aldicarb would not be persistent enough in forest or nursery soils to cause environmental problems through residue buildups. (427)

316. Because methylmercury hydroxide increases the toxicity of the insecticide carbaryl in rates, there is concern that mercury in combination with carbaryl could prove detrimental to man. Since carbaryl is considered to inhibit acetylcholinesterase, an enzyme involved in nerve mediation, the effect of methylmercury on this enzyme and a blood plasma enzyme, butyrylcholinesterase, was assessed. Methylmercury was not a direct inhibitor of these enzymes but it did seem to decrease enzyme synthesis. These findings contribute to the understanding of methylmercury influences on insecticide toxicity, an important consideration directly related to environmental safety and EPA registration of insecticides. (414)

317. Parasites are important biological control agents of forest insects; consequently, careful biological evaluations are needed for foreign parasites being considered for introduction into the United States. A European parasite, *Olesicampe benefactor*, is highly effective against larch sawfly in central Canada, and is now recommended for introduction into New York and Pennsylvania. Another parasite of several European sawfly species, *Monodontomerus dentipes*, is already established in the country and a detailed study of its life history was made to facilitate its effectiveness in controlling several species of nature sawflies. These studies provide guidelines for determining the suitability and improving the effectiveness of two European parasites for control of nature sawflies. (404,407)

318. A vast array of insects damages Southern forest trees, and identification of damage and causal agents can be very difficult. This report illustrates major insects and their damage. The illustrations are supplemented by a popularized text and keys readily understood by the layman or professional. Land managers now have a useful guide to identify Southern forest insects and the damage attributable to them. (406)

319. Illustrated, accurate, and easily understood information on insect problems in Southern pine seed orchards has long been needed by orchard managers, foresters, and entomologists. A recently prepared guide provides color illustrations and written information on 22 insect species and their related damage. Identification keys are designed for both laymen and professionals. Distribution maps, host tables, and graphs depicting principal periods of damage are further aids to species identification. Orchard managers now have the basic information to determine



damage assessments and control strategies for seed- and cone-damaging insects. (405)

320. Blister rust disease is a major limiting factor in growing western white pine in the Rocky Mountain region. A new mechanism of resistance has recently been observed. The mechanism is a hypersensitive reaction that developed in needles of *Pinus armandii* in response to infection by *Cronartium ribicola*. Knowing how to recognize this reaction will probably lead toward its discovery in *Pinus monticola*, and, subsequently, make it possible to increase its frequency and importance in this species. (568)

321. Although the spruce beetle annually kills 330-550 million board feet of spruce sawtimber, we lack sufficient understanding to effectively reduce these losses. A popularized account of the beetles' biology, life history, and natural control factors has been published. Clearcutting in irregular patches with disposal of cull logs is suggested as the most promising method of reducing spruce beetle losses. Thus, the suggested silvicultural and sanitation practices need to be tested on a large enough scale to determine their efficiency and practicability. (442)

### Pest control techniques

322. Bordeaux mixture effectively controls brown spot needle blight of longleaf pine seedlings; however, this fungicide is difficult to prepare and is corrosive to spray equipment. To find a satisfactory substitute several fungicides were evaluated. Chlorothalonil was effective and could be used in place of Bordeaux mixture in the South. (645,652)

323. Methods for successfully introducing specific ectomycorrhizal fungi into nursery soils, so that "tailor-made" tree seedlings with ecologically adapted ectomycorrhizal fungi can be produced, have been lacking. Successful methods have now been developed by which *Pisolithus tinctorius*, artificially introduced into nursery soils, infect and stimulate growth of loblolly pine seedlings. Foresters and nurserymen by use of the methods can now be assured that beneficial ectomycorrhizal formation will occur on roots of loblolly pine seedlings growing in fumigated nursery beds. (637,647,648,650,651,649)

324. Dwarf mistletoe infections can increase on young ponderosa pines selected for crop trees, thus diminishing production in managed stands. Infection can be reduced by pruning from the top, leaving a basal skirt of lower branches for photosynthesis until new, infection-free branches develop at the top of the tree. In a test of this method, pruned trees grew in height as well as unpruned trees but suffered a loss in diameter growth. Top-pruning appears to be a sound silvicultural method in mistletoe-infected, second-growth ponderosa pine stands in the Pacific Northwest. (646)

325. Fungi which cause root diseases are often difficult to control because of their tendency to spread naturally from infected to adjacent healthy root systems below the soil surface. Field trials were run to test the hypothesis that a band of roots killed by soil fumigation with methyl bromide would be unsuitable for invasion by *Fomes annosus* and would block the underground spread of this fungus from diseased to healthy trees. *Fomes annosus* was contained by fumigation in 11 of 13 infection centers located in red pine plantations in the Northeast. This information will help researchers and forest managers alike in developing methodology for controlling root rots. (644)

326. Better methods are needed for treatment of tree wounds to minimize decay development. The development of decay was inhibited for a year in wounds on red maple which had been inoculated with *Trichoderma viride*. The use of such a biological control method could be of great benefit in reducing the impact of decay in trees, especially in light of other research which points out that the commonly used wound dressings do little to stop decay. (653,654)

327. *Rhizosphaera* needle cast disease is currently causing serious damage in blue spruce Christmas tree plantations in Wisconsin, Michigan, Minnesota, and Indiana. Field tests have shown that Bordeaux mixture, benomyl, chlorothalonil, and a mixture of chlorothalonil and cycloheximide effectively control this disease. Two fungicide sprays applied in June and July provided the most economical control. This information can be used anywhere in the north central and northeastern areas where *Rhizosphaera* is damaging blue spruce. (656,657)

328. Before preparations of nucleopolyhedrosis viruses can be registered for use, methods must be found to clear the virus suspensions of certain bacterial contaminants introduced during mass production of the suspension. Sodium Omadine treatment is a rapid, inexpensive method for eliminating virus suspension contamination and should accelerate operational development of virus-based insecticides. Sodium Omadine was used to eliminate the bacterial contaminant from the European pine sawfly virus suspension. Neither the treatment nor the elimination reduced the effectiveness of the latter. (470)

329. The larch casebearer, a serious defoliator of larch in the United States was introduced into the West without any of its natural enemies. Because biological control of the casebearer by parasites is considered promising, a continuing program is underway to propagate, introduce, and evaluate parasite species. Methods have been developed for continuous laboratory rearing of the casebearer along with several parasite species and geographic strains of some parasite species are being evaluated for clarification of their taxonomic designations. A continuing program of parasite release and follow-up sampling to evaluate effectiveness is underway. In a few years, this research should demonstrate the effectiveness and feasibility of controlling larch casebearer by parasite introduction. (493,494,495)

330. Can the Douglas-fir tussock moth's sex pheromone be used to develop a more sensitive detection system for potentially destructive populations of this very explosive pest? To answer this question, chemical identification of the pheromone was necessary. The attractive compound has been identified as (Z)-6-heneicosen-11-one, and this material, now synthesized, has proved an extremely potent attractant in both laboratory and field. Traps baited with this compound are being developed to detect increasing moth populations, a prerequisite to defining areas requiring intensified surveillance and possible control measures. (500,501)

331. The European pine shoot moth is a pest of pine regeneration in various parts of the world, and new, environmentally-acceptable control strategies are needed to minimize its damage. The shoot moth's pheromone, (E-9-dodecenyl acetate) and a pheromone inhibitor, (Z)-dodecenyl acetate, were compared for their effectiveness in disrupting sex pheromone communication. Area-wide dispersion of the pheromone caused 97 percent and 100 percent reductions in male attraction to synthetic and live-female baits whereas the pheromone inhibitor produced 0 per-



cent to 63 percent reduction, respectively. Thus, the pheromone is the better compound to develop as a behavioral control agent of this insect. (467)

332. Considerable information is available on aerial spraying for control of forest insects, but it is widely scattered among many reference materials. A tabular history of aerial spraying of American forests to control insect damage has been prepared. Acreage sprayed in a given year is listed by insect and insecticide. Nearly 31 million acres have been sprayed since 1945; four insects (western spruce budworm, gypsy moth, spruce budworm, and Douglas-fir tussock moth) have been the target for 96 percent of the operations, and three insecticides (DDT, Sevin, and Zectran) have been used on 97 percent of the acreage. This record is a valuable reference for anyone involved with forest pest control. (496)

333. Mountain pine beetle is a major pest of ponderosa pine over much of the West, and methods are needed to decrease its damage. Greatest damage occurs where stand density is so high that competition has slowed growth of even the dominant trees. Field experiments and computer simulation studies indicate that thinning deserves major emphasis in programs to combat this pest. An eastern Oregon test monitored for 5 years showed that thinning reduced mortality by 90 percent and increased stand growth. The value of thinning to reduce mountain pine beetle damage has been demonstrated on a near operational scale; further work should demonstrate for how many years the treatment will remain effective and whether it is appropriate under different conditions. (497,498)

334. Outbreaks of Douglas-fir tussock moth have periodically devastated Douglas-fir and true firs in western North America, and environmentally acceptable control strategies are urgently needed to alleviate this problem. Experimental aerial applications of nucleopolyhedrosis virus and a bacterium, *Bacillus thuringiensis*, provided satisfactory foliage protection and essentially eliminated the insect from the treated plots. The success of these tests moved the two tested materials one step closer to EPA registration as operational control agents for the tussock moth. (502)

335. Microbial control agents are among the most promising of the new environmentally acceptable approaches to pest control; however, numerous safety and application problems must be solved before the effectiveness of these materials can be optimized. Considerable information is now available from many studies on spray systems, marking methods to guide aerial applications, physical properties of spray formulations, use patterns, and distribution on foliage with related effectiveness on target pests. Collectively, this information will assist those planning future applications of microbial materials. (476,477,478,479,480,486)

336. Aerial spraying to control specific insect pests must be accomplished with the minimum possible damage to nontarget organisms, and monitoring residue levels is an important method of determining possible harmful effects to wildlife. Trichlorfon and lauroyl trichlorfon, two insecticides potentially useful for controlling the western spruce budworm, were sprayed over a variety of foliage and water. Residues of both materials disappeared from the foliage in 2 weeks and from the water in about 2 days. These materials appear to present no unknown environmental hazards; thus, their continued use as experimental mate-

rials for possible control of western spruce budworm is justified. (489)

337. There is a continuing need to identify promising insecticides for control of the western spruce budworm, one of the most destructive forest defoliators in North America. Only malathion and mexacarbate are currently registered for aerial suppression, and mexacarbate is no longer commercially available. Of over 100 candidate insecticides screened over a 10-year period, pyrethroids were generally the most toxic. Several of these highly promising insecticides warrant further development as potential control agents of western spruce budworm. (491)

338. Better control agents are needed for the cottonwood leaf beetle which is a serious defoliator of young cottonwoods throughout North America. Spray chamber tests of 21 insecticides on adult beetles and seven insecticides on larvae were conducted to find candidate materials for use in nurseries and plantations. All candidates were more toxic than DDT to both larvae and adults. Some of these materials were selected for field testing in Mississippi, and carbofuran is now registered for control of this insect in cottonwood plantations. (487)

339. Better controls are needed for hemlock sawfly and the western hemlock looper, serious pests of western hemlock, spruce, and true firs in western North America. No chemicals are registered for use against hemlock sawfly and only malathion is registered for use against western hemlock looper. Of the test chemicals, tetrachlorvinphos and resmethrin were most effective against the sawfly, and pyrethrins were most toxic to the western hemlock looper. These data strongly support further studies, including field evaluations, of candidate control agents against hemlock sawfly and western hemlock looper. (492)

340. Insufficient supplies of endo-brevicomin have hampered recent field testing of pheromones to control destructive bark beetles. An efficient method of large-scale synthesis was developed that yielded no contaminating exo-isomer, a recurring problem in previous syntheses. With an assured supply of endo-brevicomin, adequate field-testing of pheromone response can be conducted for both the southern pine beetle and the western pine beetle. (475)

341. Silvicultural treatments are effective means of managing beetle populations and damage; however, in areas where cutting is not possible, other methods—such as pheromone treatment—are needed. Eight hundred trees adjacent to logging roads were baited with "Douglure" which contains frontalin, a principal component of the Douglas-fir beetle aggregative pheromone. Beetles were strongly attracted and spilled over into the surrounding stand at the rate of nine additional trees for each treated tree. In 56 percent of the attacked trees, the beetles failed to become established. These results will facilitate testing and development of frontalin for suppressing Douglas-fir beetle populations. (490)

342. Mountain pine beetle-infested material is often cut for firewood in Colorado, and the beetles can mature and become a source of infestation when the wood is moved to new locations. The beetles can be killed in ponderosa pine firewood by spraying each cord with 2 gallons of ethylene dibromide emulsion and then covering and sealing the wood piles with plastic. This is a simple and inexpensive means of preventing the spread of beetles from infested wood. (482)

343. Pinyon needle scale is a serious pest of pinyon pine in the Southwest. A cartoon-format leaflet has been developed to pro-

vide how-to-do-it information on controlling scales by working their egg masses off trees with a water spray and then destroying them. This is a simple, inexpensive control method not involving the use of pesticides that is available to any homeowner. (471)

344. Trap design is an important factor in the efficient use of insect attractants. An inexpensive trap for the southwestern pine tip moth was constructed from an ice cream carton and a board. Caged virgin females were used as baits. The use of this trap will facilitate studies to evaluate sex attractants of tip moths and possibly other species. (473)

345. The Malaise trap is widely used to collect flying insects; however, it is subject to wind damage when used as originally designed. The standard trap has been strengthened by using a bronze screen funnel and a framework of angle iron and aluminum tubing. The modified trap is only slightly more expensive than the standard and it is much better suited for use on the windswept sagebrush rangelands of south-central Wyoming. (499)

346. Scotch pine varieties vary in their resistance to Zimmerman pine moth and this resistance may be useful in controlling damage by this pest. Varieties suffering heaviest damage were from England and central Europe seed sources. Northern and Southern European varieties were similar in susceptibility, but generally less susceptible than those from central Europe. Varieties with lowest mortality by the moth also contained the lowest concentrations of the monoterpene, 3-carene that appears to be an attractant. Christmas tree growers may now be able to develop and plant Scotch pine varieties with more resistance to Zimmerman pine moth. (506)

347. Better control agents are needed for the forest tent caterpillar, a hardwood defoliator whose feeding has reduced host diameter growth 50 percent or more and prevented seed production in one-half million acres of water tupelo forests in southern Louisiana. Trichlorphon (Dylox<sup>®</sup>) applied at three-quarters of a pound per acre provided nearly 100 percent control of this insect with minimal effect on associated nontarget organisms. It is now registered by EPA. Forest managers now have an effective, environmentally acceptable insecticide to protect water tupelo from forest tent caterpillar. (484)

348. Insect pheromones offer much promise for insect survey and control applications; however, improved techniques are needed for collecting sufficient quantities of these volatile compounds to permit their identification. Several organic compounds similar to insect pheromones were removed from an airstream by absorption on Poropak Q. Application of this method to the aeration of live insects yielded a Poropak extract that concentrated the pheromone given off by the insects. This technique offers a new practical means of collecting pheromones and other volatiles that will be useful in their structural identification and evaluation as survey or control tools. (388)

349. An improved apparatus was needed for pressure-injecting fluids such as systemic pesticides into trees. Weight reduction of an existing system was achieved by use of a plastic fluid reservoir. The valving system was modified as were the injector heads to permit quick and secure attachment to the tree with duplex nails. Fungicides, insecticides, herbicides, and any other liquids can now be rapidly injected into the vascular system of trees with minimal impact on the environment. (472)

350. A practical technique is required to detect smaller European elm bark beetles in areas where their presence is unknown. To develop pheromone trapping methods, recent studies evaluated trap height and explored the relationship of captured beetles to beetle distribution and abundance. The pheromone-trapping survey technique will find widespread use in the United States and abroad for mapping beetle distribution, determining beetle abundance, and timing a variety of control programs. (488)

351. The value of *Bacillus thuringiensis* (*B.t.*) as an insect control agent has been known for some time, but improvements in formulation and application methods are needed to optimize effectiveness of treatments. Using molasses in formulating *B.t.* helps to overcome adverse gypsy moth feeding response to certain concentrations and preparations. The crystals did not elicit a discriminate type of feeding. These findings expand the potential and opportunities for successful operational use of *B.t.* against the gypsy moth and other forest insects. (507)

352. The use of baculoviruses for insect control can have short- or long-term effects depending on dosage effects and methods of application. This report contrasts short-term effects on gypsy moth (no carryover to the next generation) with long-term effects on the European pine sawfly (significant carryover). Land managers and users of baculoviruses must know what to expect of these agents and how to use them to achieve the maximum beneficial effect. (474)

353. Microbial insecticides are among the most promising approaches for environmentally safe control of forest insects, and definitive serological identification techniques are necessary for some of these materials, particularly the viruses. These reports describe the technique for obtaining antisera, and the use of the antisera to show serological similarities and differences between viruses of gypsy moth and a sawfly. The present state of knowledge concerning baculoviruses is analyzed, and solutions are offered to resolve the present confusion on methods. Standardized serological procedures are necessary for the comparison and testing of different nurseries and to obtain EPA registration for their use in control programs. (481,485)

354. Effective and environmentally safe insecticides are needed to minimize damage by the gypsy moth which continues to spread and defy a wide range of control actions. Gardona was recommended for field testing based on laboratory screening and backpack mistblower field tests. Two concentrations were applied by helicopter; both gave similar results and neither showed any significant differences with the check. Gardona failed to reduce gypsy moth populations because the study area had above-average precipitation, the spray coverage was light, and the residues dissipated rapidly from the leaves. (463)

355. Increasing registration restrictions and environmental concerns necessitate new ways to improve the infectivity and selectivity of microbial and chemical insecticides. A number of soil microorganisms were found with marked ability to dissolve the Chitin-containing mycelium of a test fungus. If topical applicants could be developed that specifically dissolve Chitin, such a material, if added to an insecticide, might significantly increase its effectiveness. (483)

356. Pheromones (attractant chemicals) are among the more promising new agents for insect control, but improved methods are needed for dispensing these materials in the forest. For the first time, an aerosol formulation of an insect pheromone was



developed and field tested. Initial results with the southern pine beetle were promising although improved quality of the aerosol and modifications of the disperser are needed. With specific improvements, a pressurized aerosol formulation of pheromone could become a valuable tool for research and for insect survey and control. (504)

357. Egg parasites are valuable biological control agents of forest insects such as fall cankerworm, but considerable biological information is needed for each parasite species before any can be recommended for introduction. A new species of *Telenomus* controlled a recent outbreak of elm spanworm in the southern Appalachians, and this parasite also attacked a related hardwood defoliator in Colombia, South America. *Telenomus* would appear to be an important parasite for elm spanworm, fall cankerworm, and possibly other species. (469)

358. Better insecticides are needed to control southern pine insects. Two systemics, Orthene and Monitor, were evaluated for insecticidal activity and persistence in loblolly pine. Root dips of Orthene protected seedlings for 60-90 days; translocation and persistence in the seedling were greater in root-dipped seedlings than in seedlings treated by soil drenching. Monitor had high insecticidal activity but was 90-95 percent metabolized within 5 days. Orthene would seem to be a useful insecticide for Southern nurserymen pending its suitable registration with EPA. (505)

359. Low seed yields in seed orchards and in controlled pollinations have hampered breeding progress in southern pines. Insect damage and lack of proper pollination techniques have been shown to contribute to the high seed losses. Lack of viable pollen and seedbugs frequently cause first year ovule abortion. Spraying Guthion in a slash pine orchard in Georgia shows promise of high seed efficiency. Improved controlled pollination techniques and insect management can lead to greater genetic improvement in southern pines. (360,468)

360. Walnut anthracnose is a disease which causes black walnut trees to lose their leaves early and incomplete maturing of nuts, a symptom known as "ambers." Anthracnose has been controlled using benomyl, either as a soil injection or a foliar spray. Better growth from anthracnose controlled trees is expected in plantations in southern Illinois. (636)

361. Coating seed with endrin is the operational method currently employed with direct seeding, but impregnating seed with such a chemical has been a long-sought goal. Research has shown that field-sown Douglas-fir seeds coated and impregnated with endrin produced much greater stocking and many times more seedlings than untreated seed, although there were no significant differences among the coating and impregnating treatments. Results reaffirmed the need for protection and clearly demonstrated that sites to be seeded must be carefully selected and sown when climatic conditions are favorable. (465)

#### Pest management strategies

362. Forest pest management is an integral but poorly understood aspect of forest resource management. A realization that forests are dynamic ecosystems providing renewable resources for many human needs accentuates the necessity to consider a great diversity of factors in developing pest management programs. The basic components of forest pest management systems and essential steps in their development are outlined. In addition, current practices and future needs for pest management in various forest types are discussed. This information

provides conceptual guidelines and specific recommendations for the development of forest pest management systems—a critical need for the maximum use of forest resources. (521)

363. Operational use of attractant-based (pheromone) suppression and survey techniques for bark beetles depends on large-scale demonstrations of their efficacy. A recent large-scale trap-out test in California against the western pine beetle appeared to (1) substantially reduce beetle populations and (2) contribute to a reduced beetle-caused tree mortality in the test area. Pending final data analysis, this test may be the first successful operational-scale use of attractants to suppress a forest insect pest. Further field or pilot testing should confirm whether this technique is an effective and economical strategy to reduce western pine beetle damage. (508)

364. Male *Ips* bark beetles produce aggregating pheromones that may be useful in survey or control operations if response specificity can be adequately determined. Seventeen species of *Ips* were tested for their specificity to the male produced attractant. Closely related species were cross-attracted, but distantly related species were not. This knowledge should facilitate development of pheromone-based, operational suppression and survey methods for *Ips* bark beetles. (514)

365. Available information on research and management of mountain pine beetles has not previously been condensed and published in a nontechnical form for foresters and other land managers. Such a guide has now been provided. This information will be useful to practicing foresters seeking ways to minimize mountain pine beetle losses in lodgepole pine stands. (510)

366. A periodic review and updating of elm bark beetle research information is necessary to adequately plan and coordinate Dutch elm disease research programs. This report summarizes past research, elaborates information on significant recent findings, and discusses future programs. This information will be useful to all researchers planning programs directed toward integrated elm bark beetle management. (517)

367. Dutch elm disease threatens to eliminate elms as a shade tree species in urban areas, but this damage can be minimized by conscientious applications of various control measures. A study of the importance of root grafts and bark beetles in the spread of the disease indicated more emphasis should be given to reducing root grafts. Control strategies primarily involve reducing bark beetle habitat and prevention of transmission through root grafts. Communities that have experienced the fewest elm losses have a sound program of several control strategies applied conscientiously over a period of years. This information can be used to good advantage by any community willing to mount a conscientious effort to save its elm trees. (509,513)

368. The integrated use of insect-suppression agents has been frequently discussed but little practiced. Both commercial preparations of *Bacillus thuringiensis* (*B.t.*) and the introduced parasitoid *Apanteles melanoscelus* have, under certain conditions, provided significant reductions in gypsy moth populations and provided some measure of foliage protection. Recent research has shown that treating a gypsy moth-infested area with *B.t.* followed by release of the parasitoid, *A. melanoscelus*, provided a greater reduction in pest populations and an increased level of foliage protection than either agent used singly. Additional research to refine application strategies and test other possible control agents may well provide land managers with a feasible integrated approach to gypsy moth control. (522)



369. Shade trees, while of concern to millions of American families, have a multitude of insect problems, the sum total of which are being studied by fewer than two dozen researchers. This report discusses a variety of pest control approaches and emphasizes utilization of parasites, predators, resistant tree varieties, and selected biological pesticides. Specific recommendations are also given in an attempt to resolve specialty-use pesticide registration problems. The International Shade Tree Conference now has the information and guidelines necessary to significantly influence future developments in shade tree entomology. (519)

370. Information on protecting seed orchards from a variety of destructive agents is widely scattered in the world literature. Now, worldwide operational procedures for protecting seed orchards from insects, diseases, mammals, birds, fire, and weather conditions such as frost, ice, and snow are discussed in one paper. This review provides a reference to the world literature on seed orchard protection that will be invaluable to all seed orchard operators and managers. (518)

371. Pales weevil is the chief insect threat to pine reproduction in the Eastern United States, and effective, environmentally safe control agents are needed to minimize its damage. Various formulations and treatments of Dursban (chlorpyrifos) and Furadan (carbofuran) were tested. This research led to the EPA registration of three formulations of these chemicals for pales weevil control. Additional information is provided on treatment strategies based on a hazard classification of the lands to be planted. Pine plantation managers now have several strategies to prevent pine reproduction losses caused by pales weevil. (516,520)

## IMPROVING THE WATER RESOURCE

### Water quality

372. Knowledge of the impact of timber harvesting on stream water quality is needed for different ecosystems. In the cedar-hemlock-grand fir ecosystem of the northern Rocky Mountains, changes in water quality caused by clearcutting and subsequent slash burning were evaluated. Significant nutrient increases occurred in stream flow through treated sites. Increases were small at downstream locations, except for one stream where downstream nutrient uptake increased as water moved laterally through nutrient enriched surface layers. Buffer strips are effective as physical barriers to direct contact with the nutrient source. (153)

373. The interruption of plant nutrient cycling by clearcut harvesting may release chemicals into soil and water systems. Old growth lodgepole pine in northwestern Wyoming was clearcut and four different methods of debris disposal were applied. Clearcutting caused insignificant nutrient increases. Burning of debris only slightly increased the release of some elements, but mulching with finely-divided logging debris caused considerable organic pollution of the soil solution in the first post-treatment year. (151)

374. Little has been reported on streamflow water quality from upland peatland watersheds. A study in north-central Minnesota shows concentrations of organically derived nutrients to be highest in the streamflow from watersheds containing oligo-

trophic peatlands. Concentrations of nutrients derived from solution of aquifer minerals are higher in streamflow from a watershed containing a minerotrophic peatland. Annual nutrient yields from upland-oligotrophic peatland watersheds are generally low and quite similar to values for other forested areas without peatlands. These data provide input to lake classification models and nutrient budgets for evaluating forest site productivity. (156)

375. Stream chemistry changes are presented for 24 streams draining both disturbed and manipulated forests. When compared with undisturbed watersheds, a grass-to-forest succession watershed that had been fertilized, limed, and herbicided showed larger losses of ions except for  $\text{PO}_4\text{-P}$ . Where the forests were cut and in various stages of natural revegetation, elevated  $\text{NO}_3\text{-N}$  discharge was evident at least 10 years after cutting, but appeared to return to baseline levels 20 years after treatment. Even mature deciduous forests that were partly defoliated by insects showed an increased discharge of  $\text{NO}_3\text{-N}$ . Conversion of deciduous forests to white pine reduced the loss of most nutrients, and young coppice forests exhibited nutrient cycles that lose no nutrients than mature hardwood forests. The results are useful in evaluating the long-term impacts of alternative forest management practices on nutrient losses in the southern Appalachians. (154)

376. The change in water quality resulting from current mining and reclamation methods is important to the maintenance of aquatic life and to downstream water users. Basic to determining change in water quality is good information on pre-mining levels of potential pollutants. Investigations in West Virginia comparing water quality characteristics from watersheds before mining with the same characteristics after mining showed significant pre-mining variation, depending on annual climatic variations and season of the year. The study indicates that correct mining methods can be employed to reduce adverse effects on stream quality. (152)

### Water yield and timing

377. When a small watershed is clearcut, it temporarily yields more water, but what happens when the trees are killed by insects, disease, or fire on an area covering several hundred square miles? Data from two large watersheds in Colorado showed that substantially greater yields are evident 25 years after a bark beetle epidemic destroyed most of the living trees. This is important information for land use planners and land managers. (722)

378. Transpiration losses may seriously deplete soil water and streamflow, especially during dry periods. A silicone antitranspirant applied to a timbered catchment in northern Idaho produced a 40 percent increase in streamflow and moisture depletion rates either less than or equal to those for a control catchment. The treatment is costly, but might be applied economically on municipal watersheds during very dry years. (50)

379. The amount and timing of water yields from forested watersheds may have serious downstream impacts. Soil water depletion was measured on cut and uncut lodgepole pine plots in glacial soils of northeastern Utah. Results indicate annual water yield increases up to 11 centimeters on well drained clearcut sites for several years thereafter until regrowth is well established. The study provides additional evidence that timber harvesting can increase water yields. (100)

380. Lack of knowledge about effects of timber harvest upon snowmelt in the Sierra Nevada has sometimes resulted in poor prediction of streamflow with resultant loss of water and hydroelectric power from reservoirs in California. Timber harvests are now being designed to change snowmelt to affect streamflow in a predictable manner. As a result, the time of delivery of water to streams can be predicted. (135)

381. A method is needed by government and private agencies engaged in streamflow forecasting for estimating snow water content from remote sites such as wilderness areas, without occupying the site. Lack of hydrologic data from such areas results in loss of millions of dollars in income annually from loss of hydroelectric power production because of inadequate operation of reservoirs downstream from such sites. A formula has been developed with which snow density may be obtained from solar radiation reflectivity (albedo) measured from aircraft flying over remote areas. This system will be of value to federal, State, and municipal water agencies and to private hydroelectric power companies. (118)

382. Inaccurate streamflow forecasts frequently occur because of a lack of information about the "ripeness," or wetness, of snowpacks under forested and open conditions. Timber harvests change the time of melt and thus wetness of snowpacks. A microwave system for measurement of snowpack "wetness" has been developed and is undergoing testing in California. The technique, which uses satellite telemetry for data gathering, is based on the attenuation of a microwave beam in transmission through snow. (116)

383. Evapotranspiration is the principal form of water loss from vegetated watersheds, but the relative losses by different species has been difficult to quantify. An inexpensive, efficient system for measuring plant-atmosphere gas exchange has been devised and used to measure transpiration from potted plants but is adaptable for measuring other gas exchanges. The system's versatility should lead to wide application in plant-atmosphere gas exchange investigations. (52)

384. Transpiration measurement of individual plants requires precise regulation of the temperature in plant enclosures. Available regulators are fairly expensive. A simple, inexpensive temperature controller utilizing thermistors has been devised. The unit will have wide application in studies requiring precise temperature control. (51)

385. Results from experiments at the Coweeta Hydrologic Laboratory are summarized in models for estimating the annual increase in water yield. Timing of the increased flow from watersheds depends on the magnitude of the increase, but results consistently show that much of the increase appears in the low-flow season. Although some increase in nutrient export occurs from forest cuttings and species conversions, the increase is well within current drinking-water standards. These facts should be used by watershed managers to achieve water resource objectives. (69)

386. Clearing forest land interrupts the hydrologic balance. Experimental cuttings on two hardwood forested watersheds in New England increased annual streamflow as much as 41 percent. Most of the increase occurred in summer and early autumn when additional streamflow is most needed. Within 4 years after complete forest clearing, revegetation caused the annual increases to almost disappear. Rotation cuttings will be necessary to maintain the increased volumes of water over time. (96)

387. The potential for possible damage to site and water quality from clearcutting has prompted various studies. Alternate strips were clearcut on a mountainous watershed in New Hampshire in 1970. Streamflow increased 54 and 23 percent for the first and second growing seasons after cutting. Electrical conductivity rose up to 30 percent due to increased leaching of ions from cut strips, but stream temperature, pH, and turbidity showed only minor changes. Increased ion output was greatest for  $\text{NO}_3$  and Ca, but values were well below those for conventional clearcuts in the White Mountains. Management options may permit making clearcuts giving significant water yield increases but with minimal environmental impact. (93,94,95)

388. The New England hurricane of 1938 uprooted or broke off vast numbers of trees in watersheds of the Connecticut and Merrimack Rivers. Annual flow in both rivers increased about 5 inches during the first year after the hurricane. Another 5 inches of increased flow occurred at diminishing rates during the next 2 or 3 years. At least half of these flow increases occurred in July, August, and September when streams normally are at the lowest levels of the year. There was no evidence of increased flow 5 years after the hurricane when forest regrowth was well underway. And there is no evidence that forest cutting, as presently practiced in the eastern United States, has measurably increased the flow in larger streams. (126)

389. Much weather information useful to foresters is collected but not published. Analyzing 10 years of unpublished information at Elkins, West Virginia showed that measurable rain can be expected every third day, with half of the storms starting between midnight and 7 a.m. Rainy weather seldom persists for longer than a week and rainless weather never for more than 2 weeks. These results also are valuable to local interests in commerce and agriculture and they always attract notice among the general public. (129)

390. Published records of streamflow may provide a huge data base at little or no cost for evaluating long-term effects of land use on water resources. Analysis of early streamflow records in Massachusetts suggests that gradual afforestation has, since 1900, decreased annual streamflow about 1 1/2 inches in Massachusetts tributaries to the Merrimack River. This analysis reinforces evidence from more costly experimental watersheds that streamflow in the eastern hardwood region decreases with afforestation. (127)

391. Water demand in semiarid areas usually exceeds the readily available supply. Snowpack management can improve water yields from productive alpine areas. Snowfences, properly constructed and positioned, effectively trap blowing snow. The accumulative snow increases summer streamflow and the amount of available water. Fences also control drifting snow on highways and in avalanche-prone areas. (117)

392. It is desirable for the research hydrologist to periodically pull together and organize all information which has been presented in individual articles, papers, and notes in a variety of publications or is unpublished, and make this information available to land managers. Detailed status of knowledge summaries have been prepared for each vegetation type in the Rocky Mountains to provide information on (1) what is known about the hydrology of the principal vegetation zones and (2) how this knowledge can best be applied to meet multiresource management objectives. This document provides the busy administrator who doesn't have the time to read the detailed reports with a



general overview and evaluation of the status of hydrologic knowledge for each major vegetative type. (110)

393. The current status of our knowledge of watershed management in the Rocky Mountains subalpine zone is presented in a recent document. Simulation models developed for subalpine hydrologic systems are described. From the review of past research, watershed management guidelines have been developed to answer the question "to what extent are we now able to recommend forest management practices to improve water yield, and still maintain acceptable water quality, quantity, and timing?" This information provides the land manager in the Rocky Mountains with the background needed for implementing watershed management principles into land use planning, and the tools to evaluate hydrologic changes resulting from different management alternatives. (111)

394. Conflicts between land use and the environment in the subalpine forest zone cannot be resolved without objective multi-resource analysis, which accounts for both primary resource responses and their interactions. Simulation models developed to predict the short term effects of timber harvesting on snowmelt and water yield have been expanded to determine the long term interactions between water and timber resources with regard to different silvicultural systems in old growth subalpine forests. The largest increase in water yield occurs when about 40 percent of the watershed is harvested in small clearcut patches. The land manager now has a planning tool designed to simulate the probable hydrologic changes resulting from different timber harvesting practices in the Central Rocky Mountains for both short- and long-term planning intervals. (112)

395. The shortage of water in the arid Southwest has stimulated research on the effects of land management practices on water yield from snow. This report documents snowmelt runoff efficiencies for several experimental watersheds in various Arizona locales where snowmelt water yield is a significant contributor to the annual water yield budget. The basic snowmelt runoff efficiency data and empirically identified inventory-prediction variables presented would be applicable to most of the ponderosa pine forests in the Southwest. (136)

396. For assessing environmental impact and other effects of forest cutting, forest managers need reliable models on which to base predictions. Analysis of the biologic and hydrologic processes suggests a more logical and general non-linear model than the simple linear one previously used. This general non-linear model improved predictions when fitted to 22 water yield experiments in the Appalachian highlands. These results advance the scientific basis for predicting water yields since the general form is flexible enough so that only local estimates of parameter values (and non new curve forms) will be required. (119)

#### Managing, rehabilitating, and improving watersheds

397. Installing soil moisture access tubes in stony and bouldery soils is difficult and can be expensive in remote or inaccessible areas. In northern Idaho, a displacing device was used to provide good contact between access tubes and soil. The method is inexpensive, causes little disturbance to the surroundings, and allows relatively easy access to remote study areas. (149)

398. The magnitude of disturbance of alpine grazing lands is rapidly increasing due to industrial and recreational developments. Revegetation of these disturbed lands is urgently needed for watershed protection and forage production. Revegetation

trials in southern Montana have shown that native species provide better long-term vegetative cover, but some introduced species give quicker initial growth. Combined plantings provide both rapid and lasting revegetation. (53)

399. The rehabilitation of surface-mined semi-arid lands presents many problems. Research at the Decker coal mine in southeastern Montana indicates several treatments that yield grass stands capable of protecting spoil materials against either water or wind erosion. Topdressing, fertilization, and irrigation have proven beneficial. Second year production was greater from native grasses than from introduced species. Land managers will use this knowledge in rehabilitation efforts. (37)

400. Acid mining wastes are difficult to revegetate and commonly are the source of soil erosion and severe stream pollution. Results of 2 years of revegetation research on acid mining wastes in central Idaho are described. Three types of main plots are used, each containing 12 treatments. The treatments are evaluated in terms of both vegetative production and ground cover, and vegetative species are evaluated in terms of their density and persistence under different treatment conditions. Coupled with a liming and fertilization program, topdressing of acid mining wastes with selected overburden materials appears to be a highly desirable revegetation practice. (33)

401. The hydrology, revegetation, and rehabilitation of fragile disturbed lands at high elevations presents special problems. Surface mine rehabilitation research underway in southern Montana includes techniques to achieve acid drainage abatement, vegetation establishment, and improved visual impacts. Related research is on plant species adaptability, plant-soil-water relations, microclimatic analysis, and photosynthetic efficiency of native-alpine plants. These studies will enable broad spectrum establishment of stable, attractive, rehabilitated lands that produce good quality drainage water. (101)

402. Estimating plant production accurately in annual plant communities is a time consuming task. An annual plant community can be sampled with minimum sample variation by using a two-stage procedure for estimating herbage yield. The analysis was done for a simulated population of *Bromus mollis* (soft chess) and should work reasonably well with other annual plant populations if used with prudence. This procedure should be useful for researchers and land managers interested in sampling herbage yield of annual plants. (122)

403. About 25,000 acres of stagnant ponderosa pine forest east of the Cascade Range in Washington and Oregon are thinned each year. A study was made on the effects of thinning to spacings of 12, 15, 18, and 21 feet on growth rate and water use by residual trees. Soil moisture depletion from heavily thinned plots averaged 3.3 inches less than from control plots during the first three summers after thinning. Tree growth was most rapid in the stand thinned to 15-foot spacing. Managers of these forest stands can vary thinning intensity to meet stated objectives. (89)

404. Good wind flow descriptions in remote areas are useful but difficult to obtain. An analysis has been developed which retains past wind speed information by computing the average speed for a small increment of travel and storage by speed and direction class. Low power requirements enable inexpensive bi-monthly data collection. (75)

405. Artificial regeneration of harsh sites east of the Cascades is difficult. In small experimental field plantings near We-



natchee, Washington, survival of Douglas-fir 2-0 seedlings increased from 45 to 92 percent after soil fumigation with methyl bromide, and vigor of both Douglas-fir and ponderosa pine seedlings improved. Biotic factors may be restricting conifer seedling development on these harsh sites. (106)

406. A large wildfire in 1970 produced greatly disturbed soils on upper elevation slopes in north central Washington. A study was initiated to test the ability of a large number of plant species to become established on sites representing 926 acres of fire-lines. Later orchard grass, Drummond timothy, perennial ryegrass, Manchar smooth brome, and tall fescue were the best adapted species. A starter fertilizer treatment was essential for successful plantings. Managers can apply this information to similar site conditions. (105)

407. Nitrogen and sulphur levels are commonly low in forest and range soils of eastern Oregon and Washington and fertilization often helps in establishing new vegetation. Sulphur coated urea was one of several treatments applied to three regionally important soils, and orchard grass was used as a test crop. Yield response varied among the three soils, but the sulphur in sulphur coated urea was available in sufficient amounts to be of acceptable fertilizer value. Slow release nitrogen fertilizer plus added benefit of sulphur makes sulphur coated urea a useful fertilizer for certain forest and range soils of eastern Oregon and Washington. (103)

408. Environmentally sensitive areas may require special protection. The impact of five traditional and advanced logging systems on soil disturbance, erosion, and understory vegetation was compared under post-fire salvage conditions on the east slope of the Cascade Mountains. Traditional systems included tractor skidding over bare ground and cable skidding. Advanced systems included skyline, helicopter, and tractor skidding over snow. Traditional systems caused more severe soil surface disturbance and consequent erosion and should be avoided for use on sites with high erosion potential. (104)

409. Forest managers need to know if road building, clearcutting, and burning influence the storm hydrograph. Based on six small watersheds in western Oregon, peak flows were increased significantly after road building but only when roads occupied at least 12 percent of the watershed. Clearcutting also changed the storm hydrograph of most streams. The maximum increase in stormflow was 16 ft. <sup>3</sup>/sec/mi<sup>2</sup> which occurred after 82 percent of a 175-acre watershed was clearcut. The design of culverts and bridges in areas must accommodate changes in peak flows caused by roads, but the changes caused by clearcuttings are not of sufficient magnitude to require significant design changes. (84)

410. Integration of research with management is needed to obtain best results in land use planning. A land use planning process was developed for Oregon's Bull Run Watershed in concert with research data from Bull Run Watershed and from the H. J. Andrews Experimental Forest. This example of active incorporation of research results in the land use planning process can serve as a planning guide. (77)

411. Future demand for southern pine products may affect water quality and reduce water yields. Water quality standards related to forest practices are being promulgated, but more information is needed to establish realistic criteria. Needed are the identification of sources and the quantification of pollutants, the development of predictive capability, and the definition of practical alternative forest management practices. Research can as-

sist management to devise practices to help prevent the adoption of unwarranted restrictions. (146,147)

412. Sand bedload additions to trout streams have been assumed to reduce habitat quality and often result in costly control measures. Daily sand additions for 4 years to a Michigan trout stream increased stream gradient and width and decreased stream depth and total static volume of water. Streambed composition changed mostly to sand and major pool filling occurred. Effects of these changes on trout populations will permit evaluation of stream damage from bank erosion or on-site construction disturbances. (83)

413. Where many lakes occur, such as north-central Minnesota, the surface elevation of groundwater lakes can be used to draw water table contour maps. The specific conductance of lake water was used to separate groundwater lakes from perched lakes and devise areal water table maps. These maps can be useful in locating wells and waste disposal sites. (85)

414. A rapid method is needed for estimating streamflow responses over a range of forest management practices. The annual water balances of a mature oak-hickory forest, a clearcut oak-hickory forest, and a young pine plantation were simulated by the PROSPER ET Model. The model used actual environmental conditions at, and closely matched responses from, experimental watersheds at the Coweeta Hydrologic Laboratory. These successful simulations led to the integration of PROSPER into a more general model which should produce a useful research and land management tool. (141)

415. The hydrologic characteristics of the forest litter layer are central to understanding biotic and abiotic processes in the litter. A model was developed to predict water content and evaporative losses in the litter of a mixed deciduous forest. The model uses readily obtainable data. Simulated evaporation and litter water content over an 80-day period showed good agreement with experimental data. The model is useful in conjunction with litter decay and mineral cycling studies and can also be utilized in fire danger rating systems. (120)

416. The 1972 Amendments to the Federal Water Pollution Control Act require that non-point source pollution from forestry activities be controlled. Erosion, primarily from mechanical site preparation, roads, skid trails and logging decks, and fire are primary sources of sediments in streams. Cutting riparian vegetation may increase stream temperature, but increases can be controlled with buffer strips. Cutting can change the nutrient content of forest streams, but chemical changes have not degraded water for drinking purposes. Using existing information, sediment and other forms of pollution can be minimized by careful planning and supervision of management activities. (68)

417. Forest fertilization in the northeastern U.S. may increase markedly in the near future to help meet many non-wood production goals. Information is needed on the use of fertilizer to enhance vegetation and prevent soil erosion for improvement of recreation sites, wildlife areas, and watershed quality. Diagnostic techniques are needed to evaluate these specialized fertilizer requirements and environmental interactions, potential pollution hazards, and other side effects. (109)

418. Planning for monitoring results of experimental treatments in forests is a complex problem. Over 60 variables are required to characterize the physical aspects of the soil-plant-atmosphere system. Each of these may vary spatially, temporally, and as a result of treatment. Availability, cost, and opera-

tion of instruments and data-logging systems may place severe restrictions on achieving the desired results. This article should help forest scientists to make the difficult decisions involved in monitoring planning. (71)

419. There is an increasing demand for more and cleaner water. More than 20 years of research in forest hydrology at the Fernow Experimental Forest in West Virginia demonstrates that water yields can be increased by tree cutting, with little or no ill-consequence to water quality. Concern that diminished soil productivity and polluted water necessarily attend wood products harvest is shown to be unwarranted. It is not practical, however, to manage forest land for both sustained increased water yield and merchantable timber products in this area. (107)

420. An unfounded belief persists that harvesting timber threatens to eventually deplete forest soils. Present knowledge indicates conventional harvest practices on eastern hardwoods pose no threat to continued forest soil productivity. Additions to the soil nutrient capital by precipitation, rock weathering, and biological processes replace nutrients removed from the site by wood products harvest. Continuing assessment of soil fertility and tree nutrition should accompany shorter cutting rotations and more complete tree utilization. These results help to reassure forest resource managers and a public that is deeply concerned with environmental degradation. (128)

421. Passage of Public Law 92-500 introduced the vaguely defined concept of non-point pollution and called for State Laws to control it in forests. The virtual non-existence of overland flow in moist climate forests bears directly on the concept of non-point pollution as well as its control in forests. The false assumption of overland flow necessarily underplays elutriation while overplaying surface erosion as causes of damage to forest soil and water resources. Fuller understanding of how water passes from sky through forest soil to streams, coupled with ability to mathematically model this passage, must provide measures to control non-point pollution that are realistic as well as attainable. (90)

422. Extremely acid mine spoils are difficult to vegetate. When used with lime and N and P fertilizers, a mulch of shredded bark assisted successful establishment in eastern Kentucky of grasses and legumes on spoils of pH 2.2 to 3.5. The mulch reduced evaporation and maintained moisture in the limed 2-4 inch rooting zone. Without mulch, only a sparse grass cover was established and rehabilitation was not achieved. (38)

423. Relative survival and growth largely determine the suitability of tree and shrub species for planting on acid surface mine spoils. Fifty-five species were evaluated on two surface mine sites in eastern Kentucky. Four years after planting, three species of birch, three of olive shrubs, and several non-commercial tree and shrub species grew well on a range of sites. Both commercial and non-commercial species should be considered by managers to reforest and protect surface mine spoils. (26)

424. Most herbaceous plantings will not survive on spoils without amendments. Lime, fertilizer, and hardwood bark mulch were applied to four problem spoil areas in Pennsylvania. The plots were planted to red pine and seeded to a mixture of weeping lovegrass, K-31 tall fescue, and Korean lespedeza. The amendments did not aid red pine survival or benefit Korean lespedeza but helped in the establishment of weeping lovegrass,

K-31 tall fescue, and volunteer vegetation. This study supports the need to apply amendments to vegetate mine spoils. (31)

425. In a study on three small watersheds near Baltimore, Maryland, water quality was improved but yield decreased when open land was converted to pine. Riparian vegetation removal improved water yield but reduced water quality. These results provide watershed managers with some guides to evaluate the effects of alternative forest operations on water quality. (62)

426. Municipalities that own entire watersheds need to know the effects of alternative land management practices on water supply and quality. In a municipal watershed study at Newark, New Jersey, conversion of oak-hickory vegetation to grass increased water yield, with most of the additional flow yielded during the summer months. These results are useful to watershed managers, especially on municipal watersheds where the area available for water yield purposes is limited. (60)

427. Effective watershed management depends on knowing the source of water yield during different parts of the storm hydrograph. A simulated rainfall study on a 7.9 hectare watershed in central Pennsylvania showed that the rising limb of a storm hydrograph is caused by precipitation falling in and near the stream channel. Upper slope conditions control peak flow duration and the decline rate of the recession limb. This information assists watershed researchers in defining stormflow characteristics and managers in watershed planning. (63)

428. More information is needed concerning the effects of forest floor characteristics on the hydrologic cycle, herbage production, tree regeneration, and fire behavior. The mean weight and depth of the forest floor in Arizona ponderosa pine on sedimentary soils averaged 7.0 tons per acre and 1.0 inch in depth, with the greatest accumulation in the H layer. These values were similar to those previously found on soils developed from volcanic parent materials. The results from this study add to our ability to manage ponderosa pine forests in the arid Southwest. (73)

429. Cattle grazing and timber production, two major uses of forested lands, are often competitive. The presence of ponderosa pine in any density will decrease the beef gain potential or livestock carrying capacity. Beef gain potential was maximum at zero basal area and was one-third less when ponderosa pine was present at basal areas of 20 ft <sup>2</sup>/ac. Physical relationships and the 1972 prices suggest that the combined economic value of grazing and saw log production would be maximum in tree stands having basal area of about 45 to 60 ft <sup>2</sup>/acre. (59)

430. To effectively manage bunchgrass rangelands within the ponderosa pine type, more needs to be understood about its ecological base. This state of the art paper documents the available physical, biological, management and economic data of the Arizona ponderosa pine—bunchgrass range ecosystem. It provides a much needed source of information for land managers and will also serve as a background for decisions concerning possible new research directions. (54)

431. Wildland managers need current information about the relative and absolute importances of the various uses and demands on pinyon-juniper woodlands, as these have changed considerably of late. Past management of pinyon-juniper woodlands gave highest priority to individual specific uses such as grazing, wildlife, and water production. Future management should result in a shifting mosaic of activities with each site managed over time for that needed product, product mix, or sequence of uses



for which it is best adapted. These findings can be applied to increase efficient use of our wildland resources. (55)

432. Ecotypic differentiation as a response to climatic conditions was studied in an adaptable grass species, *Sitanion hystrix*. The study indicates that the primary factors which influence morphological and production characteristics may be more numerous or complex than those which influence phenology: under uniform conditions, plants from warm, dry habitats flowered early and had low dry matter production; plants from cool, wet habitats flowered early and had relatively high dry matter production. The study provides valuable information about a common species widely distributed throughout the western United States. (56)

433. Land managers have expressed a need for better methods to more effectively utilize resource response information in the land use planning process. Results from watershed treatment studies in the pinyon-juniper type are examined in light of their impacts on multiple uses of the land. They show conversions of pinyon-juniper to grass can only be justified economically in cases where range improvement benefits are likely to be substantial. Conclusions generally apply to all pinyon-juniper lands in Arizona, New Mexico, Utah, and Colorado. (57,58)

434. Ponderosa pine forests occupy more than 1,650,000 acres in the Salt-Verde River Basin and supply nearly half of the total runoff in the basin. Yields of timber, herbage, and water under past management and under new experimental land treatments are reported, along with information about effects on wildlife values, esthetics, flood and sedimentation hazards, and water quality. Overall, the results of these studies now provide southwestern pine managers the means for realizing substantial improvements in the information upon which land management decisions are based. (48)

435. One of the major problems in land-use and watershed planning is in predicting what effects management practices would have on soil erosion and transport. A numerical computer model is presented that simulates the physical process systems by which water and sediment are moved overland and in stream channels. The model predicts water and sediment hydrographs and yields at downstream locations resulting from the overland flows produced by individual storms. Initial tests on ponderosa pine and pinyon-juniper watersheds have been very encouraging. This model represents a major advance in modeling the erosion process. (133,134)

436. With the complexity of managing today's wildlands, land managers have expressed a need for better methods to more effectively utilize resource response information in the land use planning process. Results from watershed treatment studies have been used to develop preliminary resource response models which will help land managers judge which alternatives best meet their objectives. These models are applicable to many planning situations, and specific information derived from such applications is being used in management decisions for much of the ponderosa pine forest land in the Southwest. Economic analysis shows that proper management can benefit all natural resources on ponderosa pine lands, even when environmental constraints are considered. (47)

437. An important aspect of runoff modeling is to solve the unsteady, gradually-varied flow problem effectively for various flow conditions. A simple numerical model for both overland and channel water routing is presented. The model includes the ef-

fects of rainfall on flow resistance and simulates hydrographs which agree very well with experimental results for both constant and variable rainfall cases. This numerical model eliminates the unstable condition often found in cases of supercritical flow and the requirement of downstream boundary conditions which are usually not available, and minimizes the complexities of applying a model to a large scale area. (113,114)

438. Fourwing saltbush is a valuable shrub that provides forage for domestic livestock, food and cover for wildlife, and protects soil from wind and water erosion in semiarid areas. These features are beneficial for coal mine spoil reclamation efforts. Soil microorganisms are lacking in coal mine spoils. Inoculation of fourwing saltbush seedlings with *Glomus mosseae* improved transplanting success in areas receiving less than 250mm of precipitation in New Mexico coal mine spoils. (41)

439. Coal spoils are deficient in plant nutrients and organic matter. Emergence and early growth of mountain rye and fourwing saltbush were studied in untreated 3-year old mine spoils, and in spoils to which organic matter or fertilizer had been added under greenhouse conditions. Emergence and growth were satisfactory from untreated spoils; adding amendments had no effect on seedling emergence or early growth. (43)

440. In low rainfall areas, supplemental water may be needed for vegetative establishment. Paraffin and polyethylene catchments were tested and found equally effective in harvesting runoff water from small storms (less than 0.45 inch). Two-month-old fourwing saltbush transplants grew more during their first growing season with this increased moisture. These methods of water harvesting were tested further on surface coal mine spoils in western New Mexico. Siberian peashrub transplants showed better vigor, and soil moisture measurements were about 20 percent greater under the treated plots. Information can be useful to those establishing shrubs on difficult sites. (44)

441. Disturbed areas, such as coal spoil banks, new roadcuts, etc., are increasing in the Southwest, and revegetating these areas is difficult in low rainfall zones. A new publication summarizes our research knowledge for establishing fourwing saltbush and alkali sacaton on harsh sites where rainfall is less than 10 inches per year. This information should be useful to land managers responsible for stabilizing disturbed areas. (42)

442. Prescribed burning in chaparral is one alternative for converting from shrubs to grass. The effects of such fires on the properties of the soil must be understood in order to minimize erosion. Relatively cool fires caused water repellency in the surface layer, while hot fires produced repellence at a greater depth. Under hot fires, however, the surface layer was rendered completely wettable. The volatilized material causing water repellence is almost completely lost above 270°C. Hot fires are more successful in killing shrubs, and are also best in terms of increasing soil wettability which would minimize erosive runoff. (132)

443. Feasibility of increasing water yield by chaparral conversion in the Southwest depends on how much water can be produced and how conversion affects other resources. Twenty years of research on small experimental watersheds show that conversion to grass substantially increases water yield and forage for livestock. If treatment areas are kept small and interspersed with native chaparral, wildlife habitat and esthetic values are preserved. While most treatment practices temporarily increase



erosion, conversion should decrease erosion over the long run. Constraints restrict conversion to about 21 percent of the chaparral, which, if converted and maintained in grass, would increase in Arizona's surface water supply by about 155,000 acre-feet each year. (91)

444. Bluegrass meadows in the Black Hills have long been subjected to intensive livestock grazing that has caused compaction of soil and possible increased rate of water runoff leading to flash flooding. Research results indicate that more than 1 year of full protection from livestock grazing is necessary for significant soil recovery and reduced summer runoff. Consequently, bluegrass meadows must be rested from use by livestock at least one full season in order to accomplish any change in soil porosity and increased water infiltration to reduce summer runoff in the Black Hills. (123)

445. Changes in shallow groundwater due to surface mining are a major concern in the Wyodak outcrop area in Wyoming because of the exceptional thickness of the coal beds. Water levels, movement, and storage before and after mining and movement in the resulting spoil material are being measured through the use of a network of wells to the top of the coal, through the coal and below the coal. These data will alert land managers, particularly livestock managers, of possible water level changes due to nearby surface mining operations. (35)

446. In order to establish plants on coal mine spoils, the properties of the spoils must be understood. Results of standard agricultural analysis for the coal spoils from the Belle Ayr South Mine near Gillette, Wyo. did not show any limiting soil characteristic that may interfere with normal plant growth. Thus favorable response is anticipated from these spoils as a growing medium. (39)

447. The removal of a 100-foot thick strata 200 feet below the surface of a 500-sq. mile area will drastically alter the landscape, particularly when there now are no real insights in the description of the topographic features. Mapping the Powder River Basin in Wyoming and Montana will provide the initial key to detect and understand subtle as well as more obvious topographic distinctions, variations, and their trends on a regional basis by quantitative data rather than by qualitative assessments. This technique will provide a scientific rationale and understanding to the regional geomorphic trends and their ecologic implications to assist managers responsible for reclamation and management of the lands after the mining is done. (440)

448. Thermistor temperature measurements are non-linear, especially over a range of tens of degrees. This precludes recording results on strip charts and magnetic tape, as well as analog computation involving thermistor output. An electronic system was developed to produce linear results suitable for recording and computation. (131)

449. Since 1970, the number of snow avalanche fatalities has doubled. Casualties can be minimized by alerting the public to dangerous conditions through a warning system. An effective warning system requires accurate prediction, for which snow slope deformation, a precursor to avalanche release, may be useful. A gage to measure deformation was developed and installed in Colorado. Such measurements may facilitate prediction of avalanches. (102,137,148)

450. Previously there has been no way to predict the profile of snowdrifts in certain terrain. A regression model, developed to predict snowdrift profiles using only topographic data, closely

duplicated observed drift profiles in Wyoming and Colorado. The Wyoming Highway Department is using this analysis to design drift-free roads. Other applications include reshaping strip-mined terrain to maximize snowfall retention to conserve moisture for revegetation. (152)

451. Snow research and management often require measurements of snow transport. A simple, inexpensive, and effective instrument for recording amounts of blowing snow was developed and tested in Wyoming. The record from the snow gage can be used to 1) determine weather conditions during drifting, 2) identify sources of blowing snow, 3) compare drifting at different sites, and 4) estimate seasonal transport. (99)

452. Quantification of the transport and evaporation of blowing snow is necessary for its efficient and economical control. A mathematical model was developed to estimate transport and evaporation of blowing snow. Predictions agree well with snow accumulations measured in Wyoming, and indicate that a significant portion of snow evaporates in-transit. The model can be used to assess effects of land management practices on blowing snow and to evaluate the feasibility of snow management practices. (143)

453. Efficient monitoring of the productivity of forage crops on shrublands of the western U.S. is needed for their proper management. Electronic capacitance meters give rapid, accurate, and non-destructive estimates of herbage yields. A double sampling technique utilizing the meter was described and tested on sagebrush, winterfat, and saltbush ranges in Wyoming, Utah, Colorado, and California. The method gave reliable yield estimates and the meter reduced sampling costs. (121)

454. Knowledge of the hydrology of sagebrush lands in wind-swept environments is needed so that better management practices can be developed to improve and protect them. In south-central Wyoming, causes and consequences of streamflow over the snow surface in channels filled with wind-drifted snow were described. This phenomenon significantly affects water yield efficiency, flood flows, conveyance losses, groundwater recharge, and sediment yields. (139)

455. Intensive recreational use of forested areas such as for skiing, may severely affect sensitive ecosystems. Monitoring the chemistry of associated streams provides a means of testing the impacts of ski area development. Road salting severely affected water quality. Sewage disposal affected inorganic water quality to a minor degree. Poma lift construction and light tree removal had no measurable effects on the water quality parameters measured. These data provide the basis for estimating impacts of a number of activities associated with ski area development. (81)

456. Research has shown that greater quantities of snow accumulate in small clearings or natural openings than under closed forest stands due to elimination of the interception loss from trees and subsequent evaporation. Research shows this explanation is incomplete and that distribution pattern rather than total snow accumulation is the main factor affected. Prevailing airflows will ultimately control the snow distribution in openings. Maximum accumulation is near the center of small clearings where airflow allows deposition. Minimum accumulation is along the leeward border. The advantages of increased accumulation and melt in openings created by logging must be weighed against the decreases in snow along downwind borders and possible detrimental effects on growth of trees along these borders. (78)

457. Water yields are important in the pine zone of the Colorado Front Range. However, they are comparatively small in contrast to yields from the high-altitude subalpine forests. Most of the soils, derived from granites, are coarse textured and have a relatively low productive capacity. These soils are potentially erosive once the protective vegetation is disturbed by poor logging practices, overgrazing, and uncontrolled urbanization. Watershed management practices can be expected to provide practical alternatives for increasing water supplies. (79)

458. Runoff and sediment production are important considerations in multiple use management of mountain rangelands. Eleven years of records from the Black Mesa Experimental Area show suspended sediment concentrations after summer storms to be as much as six times as great as those sampled during snowmelt, but total yields were small during the summer because of the small volume of flow. Based on current erosion classification schemes, proper grazing management on western Colorado mountain grasslands seems to result in little more than "geologic erosion". (76)

459. Lodgepole pine forests are important water source areas in the West. The proportion of water yield to precipitation is high because of the cold climates, short growing season, and accumulation of an overwinter snowpeak. Water quality is excellent but subject to damage by road construction. Water yield can be increased by appropriate timber harvesting techniques, but the larger amounts flow off during the natural high water season. Land managers must become increasingly aware of their influence upon water and work more closely with those concerned with water resources. (92)

460. To ensure renewal of forest resources, special logging practices must be implemented. Old-growth southwestern mixed conifer stands commonly have advance regeneration, but one-cut overstory removal with slash piling typically has destroyed most of it. Damage to advance regeneration was examined in an Arizona watershed where special care was taken to avoid damage. The selection method led to less destruction than one-cut overstory removal. Logging modifications are recommended to further reduce damage. (82)

461. Effective management of watersheds requires an understanding of their geomorphology. Criteria were developed and utilized for several watersheds in Arizona and Colorado to determine if a watershed is in dynamic equilibrium. Landform development at these sites was fully described. Geomorphology can aid in interpreting treatment efforts and in predicting if planned actions will work with or against natural forces. This approach can save time and money. (86)

## IMPROVING ENGINEERING SYSTEMS

462. Economical logging in steep terrain with cable systems is very dependent on proper planning. Research has provided simple programs for desk-top computers that tell the logging manager where to set up their yarding system on a given harvesting site and determine load carrying capabilities for a variety of alternative settings and cable systems. These programs, now in wide use, eliminate costly mistakes in steep terrain logging operations. (1217)

463. Although cable logging was used in the Appalachians in the past, tractor logging is now the most commonly used method

of extracting logs. Tractor logging is the cheapest way to log but is also one of the most damaging to the environment. Cable logging is being introduced again through several experimental studies to evaluate costs and to reduce environmental impacts and costs. From an environmental standpoint, cable logging is more acceptable. (1226)

464. Forest managers require production rates and costs for alternative logging methods and harvesting operations. This is particularly true in steep terrain. Several loggings systems including high-lead, skyline, balloon, and helicopter were studied in the logging of old growth Douglas-fir. Results provide forest managers with a means for estimating direct yarding costs which are a significant part of the total logging costs. (1219)

465. The Eastern United States has 32 million acres of northern hardwoods which are predominantly overstocked with saplings and poles while understocked with sawtimber. These stands require thinning if we are to realize their fullest quality and economic potential. A recently completed study shows that the right combinations of available highly sophisticated equipment can harvest thinnings profitably in stands considered unmerchantable with more conventional logging methods. This study provides guidelines by which a majority of these dense hardwood stands can be thinned economically and provide for maximum growth and quality of our valuable northern hardwoods species. (1214)

466. Rising prices of fuels are forcing industry to seek alternative sources of energy for manufacturing processes. A simple graphical means of estimating and comparing the cost of using wood and other residues with more conventional fuels was developed. Wide use of this technique has been made to assist industry in evaluating the potential of using wood residues as a substitute fuel. (1211)

## FOREST RESOURCES EVALUATION

### Resource Inventories

467. Current forest resource statistics are necessary to adequately monitor change. These reports present the results of the latest forest surveys of the Blue Mountain area in Oregon and Okanogan County, Washington; along with an analysis of the trends since the last survey. The data presented are regarded as essential by policymakers in the public and private sectors of the economy. (1040,1041)

468. Forest resource statistics for coastal or interior Alaska are either not available or they are dated. These reports present current information for southeast Alaska and the Tanan and Copper River inventory units of interior Alaska. The data presented will be helpful to resource managers and policymakers. (1050,1051,1052)

469. Information on forest area is a vital part of a timber inventory of a State. The 1974 survey of Iowa's woodlands shows a commercial forest area of 1,458,700 acres, about 4 percent of the State's total land area. Area in 1974 cannot be compared directly with that of the 1954 survey because of changes in definitions and survey techniques. Noncommercial forest land amounted to 102,600 acres in 1974. This information can be used by persons who grow, utilize, plan, and analyze the timber resource. (1049)



470. Because many factors affect and change the timber resources, up-to-date forest surveys are needed to determine current conditions, evaluate trends, and assess the outlook for the resource. Heavy utilization of pine and a lag in controlled regeneration have reinforced the strong trend toward hardwood dominance in North Carolina as a whole. In the Piedmont, however, the pine inventory has exhibited an upward turn. Even though volume is increasing, the amount of timber land has been declining due to renewed agricultural activity and continued urban encroachment. These findings will be useful to resource planners in North Carolina and the South. (1046,1055,1056,1057,1064)

471. Current estimates of forest resources by State and county are generally not available because of the 10-year interval between ground surveys. Through updating techniques, current estimates have been developed for Alabama and Arkansas. These data can be used in monitoring change and in formulating management plans. (1038,1039)

472. Because many factors affect and change the timber resources, up-to-date forest surveys are needed to determine current conditions, evaluate trends, and assess the outlook for the resource. A series of reports, based on the most recent survey (1974) of Louisiana, shows that forest area had declined 9 percent since the 1964 inventory, and now stands at 14.5 million acres. Softwood volume increased 31 percent, while hardwood had a 7 percent loss. The results should help in the formulation of forestry policies and programs for Louisiana. (1047,1059,1060,1061)

473. Detailed resource information is needed when making subregional management plans. A recent report presents 36 tables, by county, for various area and volume strata. Such data are regarded as essential operating statistics by numerous forest industries and public agencies. (1048)

474. Changing land use patterns favoring agriculture are adversely affecting the forest resource situation in the lower Mississippi valley. The valley's land base is not only shrinking in size, but it is also declining in terms of inherent productivity. There is an urgent need for accelerating management efforts in the potentially productive loessial region that adjoins the valley. These findings should aid decisionmaking in the private forestry sector and help policymakers in formulating public forestry programs. (1062)

475. The Southern hardwood industry has become increasingly concerned about the long-term supply of trees suitable for industrial use. A new appraisal shows that the hardwood sawtimber inventory in the South is increasing. It now totals more than 300 billion board feet (International 1/4 inch rule). The total estimate represents a gain of 15 percent since 1953. Total acreage of commercial forest land, however, is about the same now as it was in 1953. These results should provide a sound basis for developing and revising public and private forest policies. (1063)

476. Little has been done to evaluate management and marketing policies for increased timber production on tax-forfeited lands in Minnesota. Preliminary findings indicate that tax-forfeited acreage under county administration decreased 18 percent in the last 10 years. Study of marketing and management policies on county lands is basic to determination of the role of these lands in meeting future demand for timber products and recreation activities. (1058)

477. Retired crop land no longer can be relied upon as a major source of new pineland in Georgia. Activities that initiated and stimulated shifts of lands to and from pines were identified by examining previous and current trends in land use. Suggested are five courses of action that will keep one-third of the land in Georgia as pineland: reforest harvested stands to full stocking; delay harvest of loblolly and slash pine stands at least until age 30; reduce thinning and related TSI in pine stands; use TSI primarily to convert oak-pine stands to pine; stop converting natural stands of longleaf, shortleaf, pond, and Virginia pine to loblolly and slash pine. (1043)

478. An increasing demand for forest products and shrinking land base emphasize the need for achieving the full biological potential on forested acres. For ecosystems east of the Mississippi, the potential for loblolly pine is estimated to be 2 billion cu. ft. of net annual growth per year; for slash pine it is 1 billion cu. ft. And, without adding to the ecosystems, the average rate of removals in cu. ft. can be doubled in about 30 years. To achieve this potential for loblolly and slash pines, one of the most important actions is reforestation at full stocking. In addition, for slash pine, delaying harvesting until about age 30 is required. (1042,1044)

### Utilization and Production

479. A major problem of the Forest Survey is determining the drain on forest resources and keeping up with the number, size, and location of primary forest industries. Harvest of east Texas roundwood totaled 456 million cubic feet. Pulpwood, sawlogs, and veneer logs made up over 98 percent of the harvest. A total of 202 wood-using plants were in operation. Similar information is available for Ohio, Iowa, Washington, and Oregon. These data are of value to a wide range of interests, including industry, wholesalers, land managers, land use planners and development councils. (1066,1071,1076,1078,1079)

480. Pulpwood production figures are of high interest to forest industry managers and land owners in the East. In 1974, pulpwood production was 62.8 million cords. Although production in some states declined, every region showed a production advance except the Central States which showed a small decline. This information is widely used by both private and government organizations. (1067,1068,1070,1072,1073,1074)

481. Pulpwood prices differ according to location, type of delivery, species, and form. Record high prices were experienced throughout the 12 Southern States. Roundwood prices rose 19 percent in the mid South, and 17 percent in the Southeast. These data could provide a basis for projecting future price trends and can be used as a guide for buying and selling pulpwood. (1065,1069)

482. During a resurvey of New Jersey's timber resources, a study measured the losses of wood fiber attributable to clearing of forest land. An estimated 120 million cubic feet of growing stock were destroyed on the 164,000 acres of commercial forest land cleared between 1955 and 1971. Most of the recovered industrial wood fiber came from forest lands converted to agricultural use, and most of the recovered firewood came from home-building sites. By recovering and using greater quantities of wood during land-clearing operations, the Nation's timber supply can be extended. (475)

483. Soil scientists and forest land managers are often unable to communicate effectively and the expertise of the soil scientist



may not be used most effectively in management. Recent changes in policy and legal context, in amount and kind of planning and analysis for management, and advancement in planning technology are described. A general framework for land management planning has been developed in which component activities are sketched and the role of the soil scientist is described. By using this framework, soil scientists can better relate to land management and to other supporting scientific disciplines, and managers better able to effectively use fundamental soils information. (1077)

#### Inventory and Analysis Techniques

484. Sampling efficiency is an important consideration in the planning of a forest resource inventory. Theoretical analyses often go unheeded until they are demonstrated in fact. This study was an empirical analysis to contrast several sampling methods in eastern forest conditions. The results show that Sampling with Partial Replacement (SPR) is more than twice as efficient as complete remeasurement for estimating current volume. The efficiency of SPR for area estimators varies from more than twice as efficient in situations of very little area change to eight times as efficient in regions of significant change in the land use pattern. Results of this study are valuable inputs to planners of future forest inventories for eastern forests. (1082)

485. Owner attitudes, especially in the private sector, quite often determine the availability of timber and timber land for any kind of use. In three southern New England States and the States of Delaware and New Jersey, these owners have been sampled to obtain insight into the characteristics and objectives of this ownership group. In Delaware and New Jersey, the private owners indicated that they would or had allowed harvesting on their holdings. In southern New England, on the other hand, an overwhelming majority held timber land for reasons other than monetary or material gain. The results of these studies will be useful to planners and other decisionmakers who are interested in the forest and related resources of the Northeast. (1053,1054,1088)

486. The large number of tree species comprising Appalachian hardwood forests and their varying ecological requirements appear to result in more-or-less distinct associations on sites of given quality. Does the presence of certain associations prove useful in predicting site quality? Using data collected at over 100 sample locations, tree species occurrence was treated as dummy variables and related to oak site index. A procedure for easy field application of the method is presented. This system should prove useful also in other forests with a wide diversification of species. (1094)

487. A significant relation between species composition and oak site index was developed from forest survey data in West Virginia. The coefficient of determination and predictive value of individual plots, however, were low. Field use of the procedure is presented in a paper. The presence of certain associations might prove useful in predicting site quality, especially in an area such as the Appalachians where it is customary to evaluate sites in terms of oak site index, even when oak is not the primary species. (1095)

488. Future levels of timber supplies are of major concern to substantial areas of each of the Pacific Coast States. A recent study presents, in detail, the projections which were used in the Forest Service report, "The Outlook for Timber in the United

States." The localized projections will enable the individual States to view the prospects for future timber supplies and to consider the possible consequences. (1085)

489. Many people are concerned with determining future levels of employment in the forest products industry. In a recent publication, relationships are developed which provide a basis for translating future levels of wood supply and use into direct forest industrial employment. Historical trends in employment are shown; these provide a basis for extrapolating employment into the future. The report also shows seasonal variations in employment by industry sector. (1093)

490. Net volume per tree estimates are often difficult to obtain. A paper presents an equation and tables of coefficients to determine merchantable tree volume in both cubic feet and board feet, for use with a digital computer or modern electronic desk calculator. The only data needed are species, d.b.h. and site index. The results should be of interest to consulting forester, industrial forester and others interested in volume determination. (1086)

491. Most of the forest-range environment in southwest Louisiana is grazed by livestock—mainly cattle. Grazing is most widespread on the holding of forest products industries. This may reflect a new trend in the South. Certainly, the increasing application of even-age forestry on industry lands is favorable to a dual management system of raising beef and growing timber. Herbage production from southwest Louisiana's forest ranges totals 2 million tons annually. The longleaf-pine ecosystem is the most productive yielding 1,529 pounds per acre. The other ecosystems that characterize pine sites average some 800 pounds per acre with the lowland forest-range ecosystem being least productive. The average for all inventoried ecosystems is 895 pounds per acre. These findings should aid decision making in the private forestry sector and help policymakers in formulating for long-range public forestry programs. (1091)

492. We need to know how and if low resolution remote sensor data from ERTS (Earth Resources Technology Satellite) is an asset for natural renewable resources inventories. General vegetation classes such as conifer forest, deciduous forest, and grassland can be classified with 85 to 95 percent accuracy using either photo interpretation or computer-assisted analysis. Classifications for kind of coniferous forest, kind of deciduous forest or kind of grassland could not be made with acceptable accuracy by either method. Forest disturbances from natural causes or human activity could be detected with 90 percent accuracy when ERTS imagery was compared with 6-year-old aerial photos. Stress in ponderosa pine from mountain pine beetle could not be detected. These results identify the use of ERTS imagery for a first level of stratification for renewable resources inventory on a regional basis. (1087)

493. Skylab (EREP) imagery had about five times improved resolution as compared to ERTS imagery. Therefore, we needed to determine if skylab data would be an asset for resources inventories. The color photography from the earth terrain camera (S190B) provided successful (90 percent accuracy) classifications of general vegetation classes. However, classifications of specific kinds of forests or grasslands was date, film type, and photo scale dependent. Color infrared photos from the S190B would improve classification. Mountain pine beetle infestations in ponderosa pine forests could not be detected on color-combined multiband black-and-white, normal-color, or color infrared

photographs (1:2.5 million in scale) from the S190A camera systems. These results can be used to correct for solar and atmospheric effects for analyzing satellite imagery. (1080)

494. Techniques to improve range resource management planning are needed. Aerial photographs, especially color infrared, provide range resource analysts a needed tool for inventory, evaluation, and monitoring of range resources. This includes satellite and hi-flight aircraft photography for mapping plant communities. It also includes use of low-level aircraft photography for identifying and estimating selected certain plant community components such as species identification and measurement of plant cover. (1090)

495. Improvement in techniques for inventory of forest lands is needed to assess the condition and change of those lands both continuously and periodically. Recent developments in use of aerial photographs, especially color infrared, have demonstrated increased accuracy in classifying forest land, providing estimates of species composition of forest stands, making estimates of standing timber volume, and assessing impacts of insect and disease in forest stands. Thermal scanners provide a valuable system for detecting and mapping forest fires. Color films are valuable for assessing air pollution effects, wind damage and other natural or man-caused forest deprivations. (1092)

496. Nonindustrial private forest landowners hold a significant proportion of the nation's timber resource and the priorities of public programs designed to improve their management should be continually sharpened. Program managers are urged to first explicitly identify the goal they seek, then evaluate the performance of past public programs designed to achieve similar goals. Only through steps such as these can public assistance programs achieve the greatest goal accomplishment at the least cost. (1089)

497. Traditional statistical analyses are not applicable for the development of models to describe mortality or other similar responses that are dichotomous. The SCREEN computer program was developed to provide a statistically valid and efficient procedure for screening relationships between a dichotomous dependent variable and sets of explanatory independent variables. The program is applicable for a wide variety of analyses including evaluations of forest regeneration, diseases, cull volume in apparently sound trees, and patterns of habitat use by animals. (940)

498. Acquisition of timber inventory data is proceeding slowly because of the manual methods being used in many locations. Forest patterns or images on photographs and maps can be delineated, digitized, and stored by a variety of manual and automatic techniques. Investigation of a dozen different geographic information systems reflects a wide divergence in approaches. Comparisons indicate that the larger investments in computer mapping systems are most likely to have the lower inventory costs per acre. (1081)

499. Computerized methods for graphically presenting multidimensional data in two dimensions while retaining information from the original data would be of value in forest research. Recently, a general derivation was developed and a general computer program was prepared for performing the necessary computations and plots. The method can be applied routinely by using the computer program to expose features of multidimensional data which might not be discovered using less sophisti-

cated methods. The capabilities provided will be of particular use in the fields of genetics and taxonomy. (955)

## BETTERING SILVICULTURAL SYSTEMS

### Natural regeneration

500. Frost heaving, and both low and high surface temperatures, cause considerable seedling mortality of ponderosa and lodgepole pine in pumice soils in Oregon. Leaving a light slash cover on the soil surface reduces surface temperature extremes, and at the same time is the only practical means for frost-heaving protection. In areas where natural regeneration is to be featured, seedling protection and fire prevention may not be totally compatible. These results help the manager weigh the benefits and risks involved in slash prescriptions. (808)

501. To evaluate the future importance of oak stands, we need to know the sprouting capacity of northern red oak stumps and the growth of stump sprouts. In southwestern Wisconsin and adjacent Minnesota, Iowa, and Illinois results show that 30-40 red oak clumps per acre might account for one-third or more of a stand's basal area by age 20. The red oak sprouts grow exceptionally fast in height and the conventional sites index curves should not be applied. (813)

502. To make prescriptions on oak stands following clearcutting, we need to know what happens to the advance oak reproduction. Ten years after clearcutting oak stands in Missouri, stump sprouts were taller than either seedlings or seedling sprouts. The taller the advance reproduction before cutting, the faster it grew after cutting. With these guides, preharvest inventory of advance reproduction can be evaluated. (816)

503. Site utilization can be improved by developing systems to encourage natural establishment and growth of yellow-poplar and other high value species. Logging followed by control of leftover wood material is usually adequate for obtaining a satisfactory stand of yellow-poplar. Although there may be some problems with undesirable species, yellow-poplar will usually dominate the better sites. To get quality timber on highly productive Appalachian sites, grapevines need to be eliminated. A study of 40-year-old yellow-poplar stands showed that thinning could increase diameter growth of residual trees by 85 percent. Thus, increased yields and value of yellow-poplar can be expected with periodic thinnings. (815)

504. When should a longleaf pine shelterwood overstory be removed in order to promote optimum survival and growth of established seedlings? In the coastal plain and mountain provinces of Alabama, new stands developed most rapidly if released by age 3, but still responded well when released at age 8. Average seedling size and percent of the stand in height growth can be estimated from seedling age and from years of release from the parent overstory. The final harvest of mature stands can take place in a planned and orderly manner over a period of years after establishment of a new stand. (807)

505. Deficient seed supply is a problem in natural regeneration of longleaf pine. Seven years of testing in south Alabama showed that seedling establishment, survival, and growth could be improved by burning during winter or fall to prepare a seedbed. Mechanical seedbed preparation was helpful after a fire and imperative when no burn was made. Supplemental seed-



ing was needed during 5 of 7 years. Foresters can increase the likelihood of a successful seedcatch with prescribed seedbed treatments and, during marginal seedfall, with supplemental seeding. (810)

506. Alternatives to clearcutting are needed for regenerating upland hardwoods in many instances. Acceptable reproduction developed over a wide range of cutting intensity in Southern Appalachian mixed oak stands. Cutting intensity varied from clearcuts to removal of only one-third of the overstory. Species composition did not appear to be closely related to cutting intensity. Intolerant species such as yellow-poplar became established in the partial cuts as well as the clearcuts. On the other hand, subsequent height growth was strongly affected by cutting intensity with greatest growth on the clearcuts. (814)

507. Willows and cottonwoods are common colonizers on disturbed areas of the taiga and tundra of Alaska, but little is known about the seed biology of these important species. On the basis of timing of seed dispersal, these two genera can be subdivided into two groups—early seeding and late seeding. Early seeding species include both cottonwood and willow, but late seeding species include only willows. Early seeding species are nondormant and germinate completely in 1 to 2 days at temperatures ranging from 5 to 25 °C. Seed of late seeding species germinate slowly and incompletely and require stratification for rapid and complete germination. This information provides insight into the regeneration ecology of these species. (820)

#### Silvicultural methods

508. Many ponderosa pine sites in the southwest that reverted to bunchgrasses following timber harvest are now difficult to regenerate. It has been found that extracts of the green foliage of Arizona fescue and mountain muhly grasses substantially reduce germination of ponderosa pine seed and also retard elongation rate and total development of their radicles. This begins to clarify the ecological significance of the inhibitor in these grasses and suggests the need for thorough mechanical site preparation of these grass-covered areas. (835)

509. Persistent difficulties with establishing natural regeneration in the high elevation spruce-fir forests of southern Utah have generally defied conventional solutions and prompted a closer evaluation of the ecological succession in these forests. Analyses of age-class distribution of three tree species on two plateaus in southern Utah showed that Engelmann spruce, the primary species, was predominantly all-aged; subalpine fir uneven-aged; and quaking aspen even-aged. This age-class structure suggests that even-aged silviculture may not be entirely compatible with normal stand succession there, and stresses the need for testing an uneven-aged silviculture system in these forests. (828)

510. Forest managers in the central Rocky Mountains face the problem of adjusting timber harvesting practices in old-growth lodgepole pine forests to meet the needs of all key forest uses. New guidelines are now available to aid the forest manager in developing alternatives to clearcutting to meet different stand conditions, windfall risks, and insect and disease, susceptibility conditions. These guidelines provide the manager with cutting options that permit the maintenance of forest cover in recreation areas, travel influence zones, and scenic view areas. (821)

511. The completion of the harvest of old-growth redwood is rapidly approaching and there is national interest in how well this valuable forest type is being regenerated. Research on the Redwood Experimental Forest in California showed that any of three regeneration cutting methods—clearcutting, shelterwood, and selection—produced adequately stocked new stands of trees. Adequate seed coupled with mineral soil seedbed were key factors in getting seedlings established. Sprouting redwood stumps also added up to 60 percent crop trees per acre. Insofar as regeneration is concerned, foresters apparently have considerable latitude in their choice of regeneration cutting methods in this valuable forest type. (823)

512. Western bracken is a major herbaceous species on forest lands in western Oregon and Washington, often forming cover dense enough to preclude establishment of other species. Laboratory and greenhouse studies suggest that water soluble extracts from senescent bracken fronds can prevent or retard the establishment of western thimbleberry, salmonberry, and Douglas-fir seedlings. Therefore, western bracken cover should be reduced prior to establishment of more desirable species such as conifers. (836)

513. There is need for more information about harvesting systems suitable for scenic areas and severe site situations in western hemlock forests. Shelterwood harvesting in western hemlock forests produced abundant regeneration and a good site and overstory survival was good. Shelterwood harvesting is a viable alternative to clearcutting where esthetics are important or where regeneration after clearcutting may be uncertain. (838)

514. To establish black walnut on cleared forest sites, weed control methods need to be determined. In a study in southern Illinois, after 7 years trees were 17–19 feet tall where all vegetation was controlled but only 8–10 feet tall where there was no control or only control of woody competition. Controlling only woody vegetation was no better than no control at all. Walnut can be established on clearcut forest openings if weeds are controlled. (831)

515. Aspen forms the largest and most widely distributed forest type in the Lake States. It is relatively easy to regenerate because it sprouts readily from root suckers. Clearcutting or commercial harvest followed by removing the remaining overstory is recommended. A new Agriculture Handbook devoted to quaking aspen includes a summary of silvical characteristics, pests, yields, reproduction, and management alternatives. (824)

516. Although broadcast burning has been used successfully to prepare nonbrushy clearcut peatlands for black spruce reproduction, unsuitable weather, and hesitancy to use fire suggests that we need another alternative. In a 2-year trial in north central Minnesota, reproduction was rapid and adequate after a full-tree skidding operation was done. For certain conditions, this appears to be an economically sound alternative. (829)

517. Abundant natural reproduction has consistently developed on clearcuts in the Southern Appalachians. However, future species composition is usually uncertain. Ten years after a Southern Appalachian hardwood stand was clearcut on a good site, numbers of stems of desirable species appear adequate to restock the area with yellow-poplar dominating. Some problems are anticipated from grapevines, black locust thickets, and red maple clumps. (833)



518. At times, cleaning costs must be incurred if species composition needs altering to encourage development of a productive forest stand. Rejuvenation of browse or some other multiple use benefit may help justify cleaning if a major part of the cost can be assessed against that benefit. On highly productive Appalachian sites, it appears that elimination of grapevines by cleaning is necessary if quality timber is to be produced. If rotations are to be shortened for some timber species, precommercial thinning may be considered as the first of an orderly sequence of thinnings. (848)

519. Density-related mortality of pulpwood-size trees ranging from 2 to 7 cords per acre was observed in 40-year-old, high-index yellow-poplar sites on the Pisgah National Forest. By using recently developed thinning guides for pure stands of yellow-poplar, it was shown that profitable thinnings could have been made and that diameter growth of selected residual trees would have been increased by 85 percent, thereby stimulating earlier production of saw logs and veneer logs. (849)

520. Difficult regeneration problems have resulted in the continuing replacement of longleaf pine by other southern pines. Fifteen years of research and testing have shown that longleaf pines can be reliably and economically regenerated by the shelterwood system. Because of its low cost in terms of time, money, and energy, and its applicability to small as well as large areas, natural regeneration can be an attractive alternative to clearcutting and planting, particularly for the small landowner. (809)

521. Poor survival of Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) plantings in shrub-covered openings is a serious problem related to many logged-over and burned-over acres in central Idaho. The site preparation needed to reduce competition for soil moisture also exposes the site.

Protection of the site against environmental extremes is important for survival of Douglas-fir on central Idaho sites. Site preparation by scalping increased survival by as much as 42 percent and growth by as much as 30 percent on some habitat types, but not in severe habitats. When relationships between habitat type and site preparation are deciphered, prescriptions can be tailored to fit specific situations thereby reducing costs and significantly increasing survival and growth of seedlings. (830)

### Ecological Relationships

522. Aspen occurs on over a half-million acres of the more productive timbergrowing land of the southwestern United States but information on its regeneration, growth, and stand development is very limited. Studies in Arizona showed rapid and complete regeneration by aspen suckers following both fire and clearcutting disturbances. Aspen developed rapidly with the dominants averaging over 10 feet tall after four growing seasons and 24 to 40 feet tall after 22 seasons. Meanwhile, conifer dominants reached only 5 to 12 feet tall during the same period. These results demonstrate alternatives to the land manager showing that aspen stands may be regenerated with clearcut methods or fire and rapid early height development can be expected. (744, 745)

524. Massive volumes of woody residue (up to 250 tons/acre) may remain following harvests of mature Sitka spruce—western hemlock forests, and their treatment is a major managerial question which must consider numerable factions, including effects

on regeneration. A comprehensive review was prepared that includes discussions of volume and distribution of residues, decay rates, associated insects and pathogens, nutrient capital, vegetation and tree regeneration effects, and soil and stream channel effects. It provides the coastal forest manager with important background information for managing residues. (817)

525. Because slow-growing longleaf pine seedlings remain vulnerable to fire and cannot be burned for brown-spot control, brown-spot needle blight can become serious in seedling stands retained under a shelterwood overstory. Several regeneration studies in south and central Alabama indicate that the disease is much lighter under a pine overstory than in the open. Light pine overstories were less effective in suppressing the disease than heavier overstories, and hardwood canopies had no effect at all. Natural longleaf regeneration stored under parent overstories of medium densities should not develop a brown-spot problem prior to the final harvest cut. (464)

526. No universal relationships have been discovered between temperature, root aeration, or light and net ion flux to roots of intact plants from culture or soil solutions. In a recent controlled environment study, slash pine seedlings absorbed calcium, magnesium, and nitrate nitrogen from well-aerated culture solutions faster at 28° C than at 22° C or 16° C and faster at 28 than at 22° C. Phosphorus and potassium absorption was higher at 22 than at 16° C, but was not improved by further increasing temperature to 28° C. An oxygen level about 1/2 that of well aerated solutions curtailed uptake of phosphorus, potassium, calcium, and magnesium. This information will enable research scientists to eventually tailor forest fertilization prescriptions to local environments. (786)

## ECONOMICS OF FOREST MANAGEMENT

### Methods of Financial Evaluation and Planning

527. After wildfire, insects, disease, ice, or wind severely damage a stand of trees, a forester must decide whether to restock the area or to manage the remaining trees. A comparison of rates of return on investments for a severely fire damaged 5-year old slash pine (*Pinus elliottii* Engelm.) plantation in South Carolina indicated that a decision to replace the stand should be postponed for 1 year. Followup to the study proved that the decision was sound; over 70 percent of the trees survived. Forest managers can make sound, cost-benefit-based decisions by applying this procedure. (709)

528. Various studies have looked at the future timber supply to identify potential problems on a regional or national basis. But little or no effort has been made to estimate the cost of bringing forth the anticipated level of supply, nor to relate the identified supply problems to the State level where forestry programs are developed and carried out. In this paper, a static long-run economic model of supply and demand for Georgia's forest is developed. The application of such a model will help identify economic growth goals for the State and evaluate the costs of alternative reforestation methods of achieving these goals. This information is needed by industry, State, federal, and private organizations to help develop policy, set research priorities, and/or suggest action programs designed to get the job done. (1100,1101)

529. The extent to which recreation sites are utilized is becoming a necessary measurement for land management. Instant-count sampling, used in this study to measure recreation consumption, is based on the logical analogy between point sampling and on-site counting methods. One or more instant counts of visitors are made to estimate recreation use in visitor days or visitor hours. The method is particularly suitable for estimating use on small areas or sites which usually cannot be sampled economically using conventional methods. Interval-count sampling is similar but involves some theoretical differences though the basic sampling procedure is much the same. Instant-count sampling proved very efficient in simulated tests and will likely become a commonly used technique to measure recreation use. (1105,1107)

530. The implications of using the allowable cut effect in economic analysis should be recognized. This study shows how use of the allowable cut effect favors growth stimulating practices over inventory protection practices as illustrated by an analysis of the Douglas-fir tussock moth. (1096)

531. Are public forage-seeding investments in thinned ponderosa pine stands economically feasible? Research on this question has led to the development of a tool for estimating the financial return on forage seeded in thinned ponderosa pine stands. This tool is applicable to an array of forage production costs, market-based forage values, and forage production levels. It is useful to public land managers for scheduling forage-seeding investments on both forested and open rangeland. (1104)

532. The small-woodland owner is likely to decide to become a timber producer when he becomes aware of the value of his timber and the income potentials from managing his woodland. This study outlines a method for making stand evaluations that: can be tailored to individual stands and the individual owner's set of circumstances, generate stand values by totaling values of individual trees in a stand, is based on timber quality and changes in timber quality, uses on-the-ground estimates of changes in merchantable height and butt-log grade, can fit in with commonly used timber-cruising procedures, can be adapted readily to many computer programs that have been developed to handle forest inventory data and to make stand projections, focuses treatment results within reasonably short planning periods, and reserves for the owner the choice to do as he sees fit. Such an approach provides timber owners with an improved basis for deciding to become timber producers. (1098)

533. Value is a neglected dimension in timber inventories. This paper spotlights value by presenting a set of tree value conversion standards for hardwood sawtimber, by describing methods for developing and adapting them, by providing a computer program for generating them, and by showing how they can be applied to timber inventories. The availability of value standards and the possibility of altering them to fit local conditions should encourage reporting forestry investigations in terms of value as well as volume. (1099)

534. In order to make rigorous evaluations of timber stands and their development, we need volume and value measures that cover the entire range of merchantable tree diameters. A recent study provides them for pole timber and small sawtimber-sized trees—using Lake States Composite Volume Table Number 6. (1097)

535. Managers on the Flathead Indian Reservation needed

guidelines for conducting a precommercial thinning program in lodgepole pine. Economic break-even guidelines were combined with low-precision growth estimates to give a quick and inexpensive means for identifying the most promising precommercial thinning opportunities. The assessment provided managers with preliminary guidelines while awaiting precise information from a detailed response study. (1102)

536. Special user-oriented languages are needed for computer systems with complex and extensive control input, such as physical and economic simulators. MULTIFREE, a package of subroutines to translate such a language, has been successfully applied to both simulation and statistical programs. Users can employ the special language in preparing an input "memo", written in English, which the package compiles and edits into control variables passed to operational program phases. (1103)

### Timber Growing Economics

537. Private landowners are increasingly interested in the economics of producing black walnut timber. This study analyzed investment models for black walnut and demonstrated importance of combining economic guidelines with owners' objectives to evaluate black walnut investment opportunities. Results are useful to large numbers of private woodland owners interested in walnut production. (1111)

538. Most models of forest dynamics are in the form of non-simultaneous regression equations. Such models are not capable of capturing the essence of the interactions taking place between components of the stand. A study presents, through diagrams and equations, an approach to modeling forest dynamics which uses simultaneous differential equations. The information presented represents a significant departure from existing growth modeling methodology and holds considerable promise for further development. (1120)

539. Long-range projections of future timber supplies are necessary for planning wise use and management of red pine plantations in the Lake States. Projections of red pine timber supplies for the Chippewa National Forest in northern Minnesota using Timber RAM indicate that red pine sawtimber cut may be increased eightfold in the next 50 years for the Forest. Red pine sawtimber supplies will increase in similar fashion throughout the Lake States as plantations established since the 1930's mature, with potential harvest cut increasing from 30 MMbfm to 500 MMbfm for the region. Although this increase is small from a national standpoint, it is a significant increase regionally. (1121)

540. Hundreds of thousands of acres of southern pine reach thinning age each year, but labor intensive methods make thinning economically infeasible. Data on the Timberline TH-100 Thinner-Harvester, a Caterpillar 950 Tree Harvester, and a Soderhamn Go-Go Harvester suggest alternative means of making early thinnings pay. Use of these thinning systems makes it possible for forest industry to salvage otherwise unmerchantable thinnings and up growth of residual stands to expand present and future wood supplies. (1109,1115)

541. Unionization in southern forest industry seems to be increasing. This analysis of historical and legal backgrounds of labor organization gives a basis for understanding current and prospective developments. The knowledge provided can help



management adapt to upcoming changes in labor relations. (1116)

542. Foresters do not generally have a satisfactory knowledge of the existing literature on labor relations. The selected bibliography is designed to fill this void. Public and private foresters can rely on the suggested readings to increase their understanding of forest labor relations. (1117)

543. Geneticists need economic criteria for setting goals on characteristics to breed into a species. Wide ranging simulations found that genetically improved stock providing a 10-percent increase in growth could double net revenues. Genetic improvement that assures adequate growth without fertilization would make marginal sites profitable. If achieved, these genetic gains would greatly increase acreage devoted to sycamore production and output by land managers. (1113,1114)

544. Program managers are often asked to justify expenditures for genetics research. A new approach to projecting economic gains from genetically selected forest trees estimated increases in revenues from loblolly pine that ranged up to 150 percent or \$20 per acre annually. The method promises to become a valuable tool for foresters for evaluating genetic crosses, and for assessing impacts of genetically improved stock on management programs. (1124)

545. Institutional arrangements are needed in the South to achieve improved management on small tracts. Analysis of the tree farm family movement found it to be largely successful. Details of the programs vary. The results can help forest industry to establish new programs and expand existing ones and thereby increase regional timber supplies. (1122)

546. Small tract owners are not easily attracted to forest investments. By focusing on a single ideal practice such as timber stand improvement with small capital requirements, high pay-out potential, and a short investment period, owners can be induced to invest. Given a first rewarding experience, they will progressively undertake more intensive management. (1110)

547. Municipal programs to suppress Dutch elm disease have had highly variable results. Performance as measured by tree mortality was unrelated to control strategies. Costs for control programs were 37 to 76 percent less than costs without control programs in the 15-year time-span of the study. Only those municipalities that conducted a high-performance program could be expected to retain 75 percent of their elms for more than 20 to 25 years. Communities that experienced the fewest elm losses had a well founded program, applied it conscientiously, and sustained their efforts over the years. This information will be useful as guide to municipal planners in developing effective disease control programs. (1112)

548. State foresters and consulting foresters have expressed a need for an approach to include economic criteria in timber marking. The approach developed by Trimble, Mendel, and Kennell is prescribed and adapted to the TSI problem. Also, the economic requirements for precommercial investments in timber management are developed. Timber managers using these techniques in the field will produce economically sound results. (1126)

549. Resource analysts, planners, and wood industry representatives have long needed a practical method of estimating current removals of timber for local areas of the Northeast. Stepwise multiple regression analysis was used to develop equa-

tions for estimating subregional removals of softwood, hardwood and all timber. The models are easy to use and appear to work quite well for areas of a million acres or more. They provide valuable working tools for all agents concerned with the use and development of the Region's forest resources. (1118)

550. Decisions that Pennsylvania's private woodland owners make today about the use and management of their woodlands will have major impact on the future availability of forest products and services. Yet little is known about forest-related behavior of this important group of decision-makers. A study conducted to help fill this knowledge gap provided a wealth of meaningful information for assessing the role of private woodland owners as suppliers of forest products and a basis for significant policy related inferences. For example:

Most owners are over 50 years of age and are not likely to be interested in actions that yield payoffs in the far distant future.

Large acreage owners are apparently the best targets for programs aimed at improving woodland productivity since they are more willing and better able to satisfy society's requirements for forest products. (1119)

551. Economic guidelines are needed to manage lodgepole pine. Lodgepole pine stumpage values are relatively low, logging costs are higher than average, and few investments can be justified in dollars and cents. The shortest rotations producing market-sized timber generate the highest discounted values; neither schedules of commercial thinnings, low discount rates, nor the substitution of cubic foot for board foot measurement makes much difference. Noneconomic rationales or radically increased stumpage values are necessary before lodgepole pine will become of more than local importance. (1125)

552. As growth in timber demands continues to exceed growth in supplies, both public agencies and forest industries are renewing interest in small and medium-sized private ownerships as sources of additional timber. Higher production costs and other economic factors put small tracts at a disadvantage. This study attempts to measure the effects of tract size on financial returns per acre. Results indicate the major influence of tract size and suggest the large potential advantages of multi-tract or multi-ownership management. (1123)

553. Management of forests for multiple objectives presents unique resource allocation problems to today's forest managers. Goal programming (a variant of linear programming) was used to allocate 10,641 acres to eight alternative uses in order to meet, in so far as possible, a set of prescribed goals. The goal programming model was shown to be of considerable potential as an analytical framework for solving multiple-use forest management problems. (1138)

### Multiple-use Economics

554. The systems approach to studying forests has given explicit recognition to the interaction of system elements. But foresters have not had a conceptual framework to work from in attacking this problem of understanding and controlling forest interactions. A generalized framework had been suggested for ecologists several years ago by Edward Haskell but it has been almost totally ignored. We analyzed this framework for its usefulness, made minor corrections, completed it and demonstrated



its use. We anticipate that this mathematical coordinate system will become a standard tool for analyzing and reporting interactions in ecology and forestry. (1128,1131)

555. Water is often the only product from forested municipal watersheds. The once formidable barriers to multiple use of watershed forests is indefensible today. Properly located and constructed roads cause little damage from sedimentation. Dangers to health from public use are exaggerated. Watershed managers can achieve both multiple use and purity of drinking water. (1127)

556. Average costs for providing different forms of outdoor recreation are critical considerations for land-use planners. Cost-per-unit of recreation use was developed for almost all kinds of recreation sites and areas found on National Forests in the South. This work is unique in that it includes a measure of the losses in timber value, or opportunity costs, that occur from managing the land for recreation. Results indicate that the opportunity costs are generally insignificant for developed sites but become highly significant on dispersed sites such as wilderness areas. Costs developed in this study will be critical inputs for budgeting, capital improvement planning, and for pricing or setting a user fee for recreation. (1141)

557. Thinned timber stands can produce more forage for cattle in addition to accelerated timber growth when economic guidelines are used to coordinate timber and range management planning. Forage production is estimated for interior Northwest National Forests with grass seeded in timber stands that are presently scheduled for thinning in the next 15 years. (1147)

558. Future rural development in the Great Plains will result from increased activity in recreation and mineral extraction. Such development must be based on new concepts, regulations, and laws concerning land ownership, reclamation, and water use. The social and economic considerations must be carefully evaluated and a statutory basis established to guide land use planning. This paper sheds light on these rural development problems. (1129)

559. Vacation home developments grow and change in ways similar to urban subdivisions. In the early stages, they have relatively high benefit-cost ratios in respect to their requirements for government services. These ratios decline over time, and without careful planning, they can be reversed. County officials and land developers must provide early guidance to insure that these developments are not detrimental to county revenue-cost relationships in the long run. A new paper highlights problems and factors to be considered by developers and government officials in providing this guidance. (1130)

560. A sampling of the pressures for various multiple-use activities shows the complex situations created by multiple-use management, the concerns that municipal watershed managers should have, and the importance of preplanning, with particular reference to facilities shared by all the uses eventually selected as the watershed's multiple-use package. A five-step approach is described and illustrated by example for selecting multiple-use activities to feature and for adjusting a package of activities to match the funds available for shared facilities. Use of this technique will place municipal watershed land use decisions on an objective basis. (1143)

561. Very little information about Ohio's forest trails and trail users is available. Types of trails (their purpose and location) and

kinds of trail users (who they are and why they use trails) are discussed. There is important information here for trail users, planners, builders and managers attempting to optimize trail use enjoyment. (1132)

562. Private woodland owners are not motivated or able to make the investments necessary to provide adequate supplies of timber or wildlife. Incentives offer a legitimate and promising means for getting them to take action. A recent paper discusses the important role of private woodland owners as suppliers of timber and wildlife. It also presents a practical method for deriving fair incentive payments for timber and wildlife practices and demonstrates its application. (1140)

563. The economic values of all forest resources at local, regional, and national levels are needed in land use decisions so trade-offs can be quantified. A recent study found that about one-fourth of each tourist dollar accrues to Montanans as income; the proportion is highest for motel- and restaurant-dependent tourists and progressively less for hunters, fishermen, and campers. It is unlikely that growth in tourism could offset income losses resulting from even moderate declines in timber harvesting. Further, there are many differences in the nature of the jobs and in secondary economic consequences of jobs in the two industries. Land uses favoring either industry have a variety of subtle consequences. (1133,1134)

564. To guide research, a better understanding of data for land use planning is required. Socioeconomic data are used in land use planning in Idaho primarily in a descriptive, rather than analytical, manner; the necessary analytical skills are rare among planners. Planners feel that recreation data, and especially that concerning economic values of nonmarket commodities, are the most important and least available. While most planning now encompasses a time horizon of 15 years or less, projections of socioeconomic activities are needed for up to 50 years. This points up the need for more effort to provide data in a form that will be used. (1135)

565. Land use decisions of public land managers are subject to public scrutiny. Demonstrating technical credibility, structuring decision processes in ways that minimize conflicts among special-interest groups, and favoring alternatives that permit future changes in direction reduce the chance that such decisions will be reversed. (1139)

566. Consistency across groups of judges in evaluating esthetic attractiveness is necessary if such judgments are to lead to management guidelines. Four groups with differing backgrounds (undergraduate psychology students from the Universities of Michigan and Montana, Montana elementary school teachers, and Forest Service landscape architects and researchers) rated slides of forest conditions in a consistent manner. Uncut old growth and young regrowth were preferred to recently cut areas. The elementary school teachers provided the most extreme like-dislike ratings; the professional foresters provided the least extreme ratings. These findings generally support results found elsewhere in the country. (1142)

567. Sociological and economic analyses of investments in natural resources have traditionally been conducted separately. A procedure for integrating economic cost-benefit analyses with standard sociological analyses is outlined in a recent report. This procedure may aid the decision-maker in selecting those alternatives that combine long-term policy considerations with short run economic efficiency objectives. (1108)

568. With mounting pressures and conflicts in recent years over land use, the Forest Service has found itself in controversy over multiple-use of forest lands. Development of methods of economic analysis for multiple-use alternatives has proved more difficult than severest skeptics imagined. A recent study summarizes economic approaches that appear to have promise, planning methods that have been developed, and major areas in which future work must be concentrated. (1136)

### Impacts on Forest Industry and Regional Economics

569. Solution of the wood industry's pollution problems requires that they be understood in economic terms. This study examines basic economic concepts and facts needed to understand the problems, and discusses impacts of environmental and pollution control policies on the industry. Long-run viability of the wood industry does not appear to be threatened by pollution control costs. (1106)

570. What can be done when demand for pine products increases drastically? Analysis shows that the major bottleneck would be a shortage of management talent on which to expand the logging industry. Product mix changes within plants would ameliorate the problem somewhat. Price rises would shift some of the demand to western species. Forest managers need to expand timber supplies and allocate cutting on a different basis in good markets than in poor ones. (1145)

571. Reports from major timber-producing regions of the world stress woods labor problems. Analysis shows that the problem in the South is largely in pulpwood logging. To equalize employment opportunities, the prime pulpwood contractor of the future will be a multiproduct logger. An adequate supply of prime loggers with the requisite managerial ability will reduce the industry's concern for supplies of southern woods labor. The result will be greater markets for southern timber products and for stumpage combined with higher quality employment in the woods. (1146)

572. Fusiform rust is the most damaging disease of pine trees in the South, but little is known about the financial impact of the disease. Incidence data from forest surveys applied to the South indicate an annual loss to fusiform rust of \$28 million in 1972. The loss offers a measure of the possible savings from efforts by protection agencies and tree breeders. (1148,1149)

573. A thorough understanding of the wood products industry is required to conduct an effective timber harvesting program. This study found that new capital expenditures in Montana have been high, but value added per employee is relatively low. Earnings exceed those of other State industries and the United States forest products industry, but such employment is extremely hazardous. The work force is younger, has less formal education and is less skilled than in other industries. Timber harvesting supports a substantial workforce that is important to Montana's economy. (1147)

574. Assessing changes in timber harvest levels requires forecasts of consequences in dependent communities. Data are provided for each Idaho county and for broad State planning regions that define the degree of area specialization in the forest products industry, the local job dependency on this industry relative to other industries, and the local impacts of a changed

level of employment in the forest products industry. Estimates of economic consequences of timber harvest changes in the State are possible from this data. (1150,1151)

575. Forest Service unit planners do not have efficient analytic tools to complete required environmental impact assessment and to analyze the consequences of alternatives in each unit plan on the local economy. An export base model, with the required data file, analysis procedure and computer program, have been developed for local economic base analysis that permits unit planners in the Southeast to predict the economic effects of alternative proposals. Computer terminal and program are used to perform the analysis in a conversational-interactive mode. These methods enable land unit planners to better assess local economic impacts of unit plan alternatives in the Southeast. (1144)

576. To better determine future wood supplies in the U.S., the trends, needs, and potential impact of intensive culture of public and private forests need to be assessed. A nationwide survey indicates that although investments in cultural practices will increase greatly in the next decade, annual wood harvests from industrial lands are expected to increase only 10-15 percent. Similar investments on National Forest, other public, and small private ownerships will be needed to effect any major increase in total national wood harvest. This information helps managers determine national needs and priorities for intensive forest culture. (1152)

577. Intensive management of short-rotation crops will be highly expensive and must be evaluated carefully. An analysis was made that lists factors affecting production of forest crops; provides estimated costs per acre of land, land preparation, planting, management, harvesting, hauling, and processing; and discusses their management implications. Data presented are useful for economic assessments of short-rotation systems. (1083)

## WEATHER MODIFICATION AND WEATHER EFFECTS

578. Accurate knowledge of the surface temperature, relative humidity, and wind velocity is necessary for estimating fire danger and fire spread in forested mountainous areas. A meteorological research telemetering network accurately measures temperature, relative humidity, windspeed and direction, and net radiation. These data are being used to: (1) Validate and improve mathematical models for diagnosing and predicting these weather elements in mountainous terrain; (2) determine optimum number and placement of meteorological observing stations for an operational network in southern California; and (3) develop adequate interpolation techniques for the operational network. (734,735)

579. Wind variations in a forest clearing can cause snow to accumulate and trees to blow down. This study investigated the nature of wind distribution in a clearing in an even-aged, somewhat idealized lodgepole pine canopy. Eddies were found to shed periodically from the upwind surface of the clearing. This phenomenon will complicate efforts to model wind effects of forest clearings.. (712)

580. The wind field in mountains is the single most difficult factor encountered in evaluating forest fire spread and pollutant dispersion. A simple, one-layer model of atmospheric boundary

layer flow was developed for use in complex terrain. The model requires much less data than traditional approaches; therefore, it can be used as an estimator of wind patterns in areas where dense observational networks are not economically feasible. The model is intended for use primarily in fire behavior prediction but also has application in the evaluation of pollution transport patterns. (732)

581. Modeling the behavior of western mountain watersheds requires a detailed snow melting simulation. Snow melts because of an input of energy to the surface; therefore, a model is proposed for the solar albedo of natural snow cover. The model suggests that for grain sizes larger than 1.5 mm, density is the primary factor governing albedo. This information is necessary to determine the melting characteristics of a snow pack. (531)



# IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES

## INTENSIVE CULTURE METHODS

### Site Evaluation and Soil Improvement

582. Frost heaving is a leading cause of tree seedling mortality in many parts of the world. Studies in Arizona show that the rate and amount of frost heaving increases with increasing bulk density, that indexes utilizing bulk density and sand content of the soils are useful predictors of frost heaving susceptibility of forest soils, and that measures which lower bulk density, such as plowing or disking, reduce heaving. These results help the forest manager detect where tree regeneration may be adversely affected by frost heaving and offer some possible measures for reducing this damage. (812)

583. Thinning dense forest stands generally stimulates growth, but the relationship of nutrient levels to stocking density after thinning has not been established. Eight years after thinning of a 43-year-old pine stand in Arizona, the total forest floor litter component weights and total nutrients were found to be directly proportional to the basal area stocking level. However, the tree foliar nutrient concentrations were not affected. The longest and heaviest needle fascicles were found on the area with the least basal area stocking. This basic information is essential for more fully evaluating stand density effects in ponderosa pine forests. (761)

584. Clays play an important role in forest soil nutrient and water status, affecting tree regeneration establishment and subsequent growth, but some of the basic soils information needed for assisting silvicultural and management prescriptions is inadequate. An analysis has recently been completed of the types and amounts of clay minerals found in many Montana soils. Mica contents are generally high in the forested soils of western Montana, and many of the soils there have a thin mantle of volcanic ash containing amorphous clays. These results provide basic information for evaluating soil-dependent forest management activities. (759)

585. Accurately evaluating forest site quality has been a major problem since the beginning of forestry in America, and a large volume of sometimes confusing and contradictory literature has accumulated for most of our important tree species. This comprehensive review traces the history, summarizes the present status, and suggests site quality goals for the future. The coordination and integration of all site evaluation methods is emphasized, as well as integration with yield prediction and methods for landscape classification and mapping. (756)

586. The growth rate of planted slash pines varies considerably on sandhill sites. Examination of sandhill soils in 91 plantations established in west Florida called attention to the tremendous variation in physical characteristics. Layers of fine-textured soil found at various depths in these excessively drained soils are known to retain moisture longer than sand and to retard percolation of water through the soil profile. In the

sandhills, slash pine grows best where fine textured soil is not more than 12 feet below the surface. Site index decreased 1 foot for every 9 inches of depth to the fine textured soil. Site preparation does little to alter the inherent productivity of sandhill sites. This information will help land managers to identify those sites within the sandhills suited to slash pine. (757)

587. Soil nitrogen status might be improved if the factors that control nitrogen fixation in forest soils were known and could be manipulated. In the South Carolina Coastal Plain, nonsymbiotic nitrogen fixation was less than 1 Kg/ha/yr in upland mineral soils but over 10 Kg/ha/yr in swamp soils. To get high nitrogen fixation in upland soils, an addition of phosphorus and an energy source were required. In loblolly pine stands, an available energy supply of leaf litter is limiting and a significant increase in soil nitrogen by nonsymbiotic fixation does not seem feasible at this time. (758)

### Artificial Regeneration

588. Artificial seeding of ponderosa pine after timber harvesting in the Sierra Nevada of California has been unreliable for establishing new stands. A seeding study there shows that 400 seedlings per acre can be established by 1) preparing 100 percent of the site by piling and burning slash and residual vegetation; 2) treating seed with endrin-arsan-aluminum dust pest repellent treatment, or equivalent; and 3) seeding at least 10,000 viable seed per acre. This prescription for seeding ponderosa pine in the westside Sierra Nevada forests is a reliable management option which is cheaper than planting. (897)

589. Planting is the most reliable method of regenerating ponderosa pine in the southwest but planting is expensive. Tests in Arizona showed that spot seeding of pine produced consistently more seedlings than broadcast seeding, that frost heaving and drought accounted for most seedling mortality, and that direct seeding results were extremely variable, even on the most favorable sites. Because there is no net cost advantage of direct seeding over planting and the success rate is less predictable than with planting, direct seeding should be reserved as a flexible tool to promptly regenerate only the best sites when planting stock is unavailable. (900)

590. The traditional fall season for prescribed burning of logging slash in larch forests of the northern Rockies has been too short, and we haven't known how effectively we could prepare a seedbed by burning during other parts of the season. Studies in northwest Montana show that to accomplish near-complete duff reduction, north aspects had to be burned during the summer before the onset of heavy autumn rains, but that the other aspects had a much longer time period in which to burn effectively. Spring burns did not significantly decrease the duff layer on any aspect. The burning conditions required to prepare an adequate seedbed are now better defined, and more precise burning prescriptions can now be made for larch forests. (819)

591. Reforestation efforts are rapidly becoming more dependent on containerized tree seedlings, but supporting information

is fragmented and incomplete. Several recent reports broadly summarize the status of container-grown seedling production and use, present guides for starting greenhouse container operations, describe new devices and techniques, compare containerized and bare root systems, and describe problems yet to be resolved. These reports provide reforestation specialists with information needed for developing and evaluating containerized tree seedling programs. (902,905,906,907,909)

592. Hardwood nurserymen need a way to prevent seedlings from becoming too large to handle effectively. Two growth retardants were tested for nursery use to control size of five hardwood species. Alar slowed growth of lilac and cotoneaster. Slo Gro stopped growth of Siberian elm and slowed growth of honeysuckle and cotoneaster. Chemicals were less effective than undercutting on green ash. With proper use of growth retardants on some species, nurserymen can carry over and sell stock that would otherwise have to be destroyed. (908)

593. Expanded planting programs on National Forests have forced nurserymen in some cases to adopt high density sowing rates of forest trees in nursery beds. A bed density study at Wind River and Humboldt nurseries in the Pacific Northwest showed that seedling stem diameter and field height growth decreased as bed density increased from 10 to 70 trees per square foot. Therefore, increased nursery production probably should be obtained by expanding nursery bed space rather than by growing seedlings at higher densities. (885)

594. Adverse environmental conditions and/or poor choice of seed source can hinder successful plantation establishment. In the case of basswood in Indiana and Illinois, site proved to be more important than seed source. Clearcut openings were a much better environment for basswood development than were old fields. Intensive care is needed to insure success for basswood plantation establishment. (822)

595. Eastern white pine is widely planted in areas outside its natural range and we need to determine the best adapted sources of seed. Test plantations in Illinois, Indiana, and Kentucky all showed similar results with the best sources 70-80 percent superior to the species average. A large seed collection zone comprising most of the southern part of the natural range is recommended for white pine seed collection for use in the Ohio Valley plantings. (887)

596. The cost of converting Sandhill land from scrub hardwoods to pine can be reduced substantially if seeds instead of seedlings can be used to establish such plantations. A recent study showed that longleaf and Choctawhatchee sand pine can be successfully established from seed if the sites are thoroughly prepared, and if the seeds are covered with a thin layer of soil when sown. Well-stocked stands developed where cultipackers drawn by farm tractors had been used to cover the seeds. Machine seeding either longleaf or Choctawhatchee sand pine in rows affords managers of Sandhill land in the Southeast an opportunity to conserve about half of their seeds, to space seeds accurately, and to complete distribution covering of the seeds in a single operation. (894)

597. Warm, wet summers offer an opportunity to extend the season for converting millions of acres of droughty, scrub hardwood-dominated Sandhills land in the Southeast to pine by direct seeding. Results of planting longleaf, slash, Ocala sand, and Choctawhatchee sand pine seeds at biweekly intervals for two consecutive years show that direct seeding during the summer is impractical. However, seedling establishment was best when

daily high temperatures averaged no more than 71°F (22°C) and daily lows no less than 38°F (3°C) during the 10 weeks after seeding. Where local guidelines are lacking, these findings can be used with published climatological data to determine the best time to seed the four pines. (884)

598. Sand pine seedlings produced within their natural range of Florida and coastal Alabama seldom remain dormant throughout the entire winter. Consequently, storage, handling, and transplanting of these seedlings is more restrictive than for other southern pines that usually remain dormant. It has been found that transplanting success is best if sand pine seedlings are lifted in January or early February in quantities than can be planted within 1 week after lifting. Bales or bags of seedlings should be stored unstacked under shade. Land managers are advised to order the Choctawhatchee variety of sand pine in preference to the Ocala variety and to follow recommended storage and handling procedures. (882)

599. The cost of reforestation in the Sandhills of the Southeast would be substantially reduced if sand pine could be planted with little, if any, site preparation. Through age 5, Choctawhatchee sand pine (CSP) planted on prepared sites attained an average height of 10.6 feet with 95 percent survival. Under these same conditions, Ocala sand pine (OSP) reached an average height of 12.2 feet with 90 percent survival. When planted in the woods, CSP attained an average height of 5.4 feet with 84 percent survival through age 5. Under the same conditions and in the same period of time, OSP attained an average height of 7.6 feet with 74 percent survival. Sand pines planted on prepared sites seem destined to produce more wood sooner than others planted in the woods. (883)

600. Economic success of hardwood planting programs depends on the ability of seedlings to survive and grow rapidly. Sweetgum seedlings with root-collar diameters greater than 1/4 inch survived and grew better than small seedlings. Morphological grades of sweetgum seedlings are a good measure of early growth potential. (878)

601. Increased wood demands have focused attention on the production potential of hardwoods. Intensive cultural practices have now been developed for the management of commercial hardwood plantations in the South. Careful choice of planting areas, thorough site preparation, graded planting stock, and intensive cultural treatments are essential to assure plantation establishment. Growth of plantations grown under intensive culture averages between 3 and 4 cords per acre per year. Practical methods are now available for growing hardwoods under several management systems and for different product goals. (879)

602. Artificial regeneration with desirable oak species may be one way to improve the culled, understocked hardwood stands of Tennessee's Cumberland Plateau. It has been found, however, that white, northern red, and black oaks can be established by direct seeding only if acorns are protected and competing vegetation is controlled. Survival after 4 to 7 years averaged 42 percent in coves and 70 percent on upland plots. Height growth was slow. This information provides regeneration specialists good insight about the requirements of successful direct seeding. (895)

603. Little is known of the effect fertilizers have on longleaf pine seed production and quality. Eleven years of data show that complete fertilization increases cone production and seed size, but does not influence the number of seeds per cone, proportion of empty or wormy seed, cone size, initial viability, or keeping



quality. Correlations between adjacent years for cones per tree, sound seeds per cone, percent empties, seed weight, and cone size show these are characteristics of individual trees, but storage quality of seed is not. Germinability is not associated with number of seeds per cone, cone size, or seed size. These data will be useful in management of longleaf seed orchards and to scientists working with pine seeds. (891)

604. Finding a practical, effective container is essential for planting tubelings in the South. Survival and growth of 6-week-old containerized loblolly seedlings grown in soilless wood-fiber blocks were higher than in soil-filled Kraft-paper tubes when outplanted at the same time. Survival of longleaf seedlings in blocks was lower than in tubes, but growth was markedly better. Although growth from a late August planting was not satisfactory with either species, results show that soilless blocks may provide an improved means for regenerating southern pines in certain situations. Results will be useful to foresters and nurserymen evaluating containerization materials for southern use. (875)

605. The normal cone collection period for southern pines is only about 3 weeks. By storing cones for 5 weeks at air temperatures, collections of slash, loblolly, and longleaf can be started several weeks earlier than usual without impairing seed yields or viability. Yields increased with increasing lengths of storage from 1 to 5 weeks with all species. Germination of slash pine was increased by long storage for all dates of collection, had no effect on longleaf and loblolly, except it decreased viability from the earliest longleaf collection. The annual harvest of southern pine seed can be almost doubled in many situations by applying this information. (892)

606. Use of an aerial multiple-row seeder will overcome most of the objections of broadcast direct seeding, and still retain its advantages. A test was installed to determine if the downward velocity given the seed to reduce deviation within rows seriously affects viability or causes excessive penetration into mechanically prepared soil. Loblolly pine seeds, given a clay coating were sown on different soil-type and site-preparation treatments. Soil penetration was not a problem and viability was not reduced unless seeds hit some hard object such as a rock or stump. Results should benefit silviculturists, artificial regeneration specialists, and agricultural engineers interested in further development and utilization of the aerial row seeder. (877)

607. Information on managing southern pines is available, but no single authoritative source exists. Proceedings of a recent symposium assembles 53 papers on virtually every aspect of southern pine management. They cover such diverse topics as regeneration techniques, precommercial thinning, insect and disease control, growth and yield, landscaping, range and wildlife opportunities, water resources, tree improvement and genetics, and Federal income tax guidelines. Managers of southern woodlands will find the proceedings to be a valuable source of useful information. (853,890,923,924,928,952)

608. Increased production of sycamore seedlings for planting in the South is hampered by the problem of low percentages of filled seeds in many lots. However, tests over a 3-year period have demonstrated how empty seeds can be mechanically separated from filled seeds. Small samples can be upgraded to 90 to 100 percent filled seeds with laboratory blowers. Medium- to large-sized lots of 20 to 30 percent filled seeds can be upgraded to 50 to 68 percent with a gravity separator. Southern nursery-

men who grow sycamore can reduce cold storage requirements by as much as 75 percent and nursery costs by as much as 25 percent by the recommended seed handling procedures. (881)

609. Special tests of seed lot vigor are needed for complete evaluation of seeds. Tests with cherrybark oak acorns of variable quality show that germination rate is significantly correlated with tetrazolium staining, growth, and exhaustion but not with oxygen uptake or carbohydrate leakage. None of the tests correlated significantly with germination percentage. Seed scientists now know which tests have promise for future work and which ones can be eliminated from consideration. (880)

610. Interpreting radiographs is difficult because of superimposed images and because sectioning and photographing are destructive and time consuming. Tomograms provide clearly distinguished internal structures of predetermined planes at 1 mm. increments in large tree seeds. The major advantage over radiographs is that actual measurements may be determined within 1 mm. A specialized instrument is required for this technique, but film and developing are standard as for radiographs. This technique is significant to anatomic, taxonomic, and pathologic investigations, as it leaves the seed undisturbed and viable for germination. (911)

611. Control and regulation of germination is stymied in some species by a lack of understanding of the underlying causes of seed dormancy. During stratification and germination, carbohydrate and lipid contents in water oak embryos diminish, and both substances shifted from cotyledons to embryo axis. Carbohydrates, lipids, and proteins move to the root apex as germination is completed, but proteins, unlike carbohydrates, originate near the shoot apex and not in the cotyledons. This information contributes greatly to the research effort, which seeks to learn the cause of tree seed dormancy and how we can control it. (912)

612. Many clay soils in the lower Mississippi River Valley are subject to annual overflow. Tree reproduction on such sites is slow growing and tends to undesirable species. Ten- and 14-inch cuttings of 1-year-old green ash planted horizontally 1 to 3 inches deep on problem sites in northern Mississippi sprouted and grew well, as did vertical cuttings and seedlings of the same species. The technique provides an alternative for reproducing a highly desirable species on difficult sites using mechanized equipment. (888)

613. Because of limited equipment, it is sometimes necessary to start picking Douglas-fir cones before the ideal collection date. It is important to know whether or not early collection causes any problems. A case history of 309 trees in Oregon showed that seed collected more than 3 weeks before seed fall begins was much more difficult to extract, was lighter, germinated less than half as well as normal seed, and produced weaker seedlings. With this knowledge, forest managers are forewarned not to collect seed before it is fully ripe unless they are willing to sustain certain losses. (898)

614. In the humid, lowland tropics of Puerto Rico, tree seedlings must grow rapidly if they are to outgrow weeds and be successful. Three species of Eucalyptus, planted on different sites, survived and grew acceptably and look promising for reforestation in Puerto Rico. (913)

615. Container-grown forest tree seedlings are being planted in increasing numbers because of better survival and faster initial growth rate, but containers can produce malformed root systems that cause windthrow, retarded growth, or even death



many years later. A 2-year evaluation of *Pinus ponderosa* seedlings grown in different containers showed that seedlings grown in containers with no walls had no more spiralling than seedlings that had never been in a container. Seedlings grown in containers with vertical grooves have less root spiralling than ones grown in smooth-walled containers. A method has thus been found to insure that the early benefits of container-stock are not negated later in the life of the tree. (904)

616. Establishing Douglas-fir seedlings on hot, south-facing cutblocks is often a difficult task. Deep planting and stem shading—techniques that often improve growth and survival of other species on droughty south slope sites—failed to benefit Douglas-fir planted in northwestern California. Although survival rates were the same, February plantations on this 2000 foot elevation site averaged 20 percent greater 10-year height growth than did the March plantations. These results should help improve planting results on the low elevation sites of northwest California. (903)

617. Nursery stock performs best if lifting and transplanting are done when the stock is dormant. A method of readily determining dormancy is now available. It employs a portable square wave generator and oscilloscope. The physiological state of the plant can be determined from an electrical response which can be evaluated by the shape of the transmitted wave form displayed on the oscilloscope screen. This tool should prove valuable in determining the proper time for lifting nursery stock. (886)

#### Stand Improvement

618. Effective and inexpensive methods are needed to thin pole-size hardwoods and control undesirable hardwoods in the Ozark Mountains. Tordon 101 and 2,4-D were injected into a large number of hardwood species in the dormant and growing seasons. Tordon was generally more effective than 2,4-D and tended to cause crown kill sooner after dormant season application. Both chemicals were effective when applied during the growing season on all species tested except red maple, ash, and dogwood. These results will help land managers determine effective methods of hardwood vegetation control to suit their objectives. (855)

619. *Saligna eucalyptus* is a high yielding species in Hawaii plantations but little is known about culturing it in stands. Studies show that thinning these plantations (10 × 10 foot initial spacing) at age 6 to three different basal area levels resulted in no significant improvement in growth over that of the unthinned plantations. These preliminary results indicate thinning should probably be delayed until age 15 when basal area approaches 200 sq. ft. per acre. These results suggest that management costs can be held down without jeopardizing growth of young eucalyptus. (873)

620. On high rainfall areas in Hawaii, planted tree seedlings must grow rapidly to compete successfully with other vegetation. Fertilizing Australian toon and Queensland-maple seedlings with slow release Osmocote at the time of planting at least doubled the height growth over that of unfertilized counterparts. As a result, less than one-half as many of the fertilized seedlings require maintenance to prevent their being overtopped by competing vegetation as do unfertilized trees. These results indicate that savings in maintenance costs are possible by fertilizing seedlings with Osmocote at the time of planting. (871)

621. Precommercial thinning in coastal Douglas-fir forests is a generally accepted cultural practice but when, how, and where to thin needs to be better defined. Improved guidelines for precommercial thinning in Douglas-fir stands have been developed. Precommercial thinning prescriptions depend strongly on size of trees desired at the first commercial cut; the larger this size (1) the fewer trees should be left after thinning, (2) the greater is the tree size at which thinning is practical, and (3) the greater is the gain in usable yields. The new guidelines will help determine feasibility of precommercial thinning practices in young Douglas-fir forests. (865)

622. Thinning and fertilization are both recognized as methods of increasing usable wood production, but fertilization responses are largely unknown for lodgepole pine. Fertilization with N, P, and S produced large increases in lodgepole pine wood volume and understory grass production the first 4 years after application. Indications are that radial wood growth will continue longer than 4 years. These and subsequent results will help determine the feasibility of fertilization in lodgepole pine forests. (843)

623. As forest management intensifies in the mixed conifer forests of eastern Oregon, information is needed on growth and yield of managed stands so stocking level regimes can be formulated. Results from a western larch thinning study showed that 55-year-old previously unmanaged larch responded moderately in diameter growth as stand density increased, but height growth was not affected. Thinning from below produced more favorable results than thinning from above. This information corroborates other findings that encourage early stocking control of this important intolerant species and discourage thinning from below. (867)

624. Herbicides are useful for site preparation and release on forest lands in the Pacific Northwest but precise prescriptions are needed for them to be effective. A working manual now available summarizes 20 years of research and experience on herbicide use and treatment prescription. Included are five basic considerations: (1) herbicide selection, (2) amount of herbicide, (3) herbicide carriers, (4) spray volume, and (5) seasons for application of herbicides. This information will enable the forester to better select herbicidal treatments keyed to silvicultural objectives attuned to variations in plant communities and environmental conditions. (856)

625. Overall nutrient cycling and fertilizer effects in Douglas-fir and western hemlock forests of the Pacific Northwest are largely unknown. Factors beginning to emerge include findings that (1) conventional harvesting can remove substantial N from the ecosystem, (2) hemlock growth response to fertilization appeared higher in vigorous stands and more consistent in the Cascades than along the coast, (3) foliarly applied nitrogen solution produces growth response similar to that of urea prill application, and (4) light nitrogen fertilization in young Douglas-fir reduced aphid populations by about 50 percent. Nutrient status and fertilizer responses are still highly variable but information such as this is a leading toward better understanding. (847)

626. To maintain rapid growth of black walnut trees we need to know when and how to thin plantations. A stocking guide which is based on crown competition factor provides a biologically sound, flexible tool for guiding thinning operations. Large benefits can be derived by planting more trees than are needed

and by selecting the better individual trees as the plantation develops. (866)

627. Quality of pin oak for lumber is low because of dead branches that persist for many years. In a study in Missouri, 12 years after pruning, bole quality was improved. Although there was some epicormic branch sprouting, almost all sprouting on the pruned trees occurred within the first 4 years after pruning. (859)

628. To maximize wood yields intensive cultural methods and improved genotypes must be explored and defined. Very short rotations (3 years) of *Populus* species grown at spacings of 9 × 9 inches produced over 4 tons/acre/year of dry weight wood in northern Wisconsin. Although nearly all wood quality traits varied between clones, they were well within the ranges reported for *Populus* pulpwood. Differences in yield between two clones demonstrate the potential for making gains through genetics. This maximum fiber yield approach appears to be an alternative for meeting increased demands for pulpwood in the Lake States. (233,844,845,846)

629. The supply of high quality yellow birch logs has dwindled in recent years and ways to speed the growth of existing trees are needed. Yellow birch saplings released before age 16 developed larger crowns and increased diameter growth. Crown release or selection thinning of saw log-sized trees yielded a 50 percent increase in diameter growth over unreleased trees. Fertilization increased lateral branch elongation in the upper part of the crowns, but did not increase diameter growth during the first 3 years. Thinning yellow birch stands in the Lake States can be expected to reduce rotation age and alleviate the problem of high quality material. (850,851)

630. The nutrient cycle holds the key for continuously productive management of loblolly pine plantations. The quantity of nutrients taken from the cycle through harvest and the supply available for subsequent rotations depends upon the fertility of the soil, length of rotation, and the proportion of the tree removed. Twice as much N is removed when all aboveground portions of loblolly pines are removed than with conventional pulpwood harvesting to an 8 cm top. Young, fast-growing trees utilize available nutrients faster than older trees. Total tree removal and short rotations remove more nutrients than conventional harvesting and long rotations. On some sites, the consequence may be a decline in productivity and a need for fertilization. Forest managers must take the nutrient cycle into account if successive rotations are to be profitable. (746,753,754,872)

631. Interplanting is sometimes used to bolster stocking, especially under cost-sharing programs that require minimum stocking for payments. Results on the Holt Walton Experimental Forest in south Georgia show that slash pine plantings originally spaced 12 × 12 and 15 × 15 feet cannot be successfully interplanted 1 year later. In two of nine plantations, interplanted trees contributed only 267 cubic feet of merchantable volume at age 25, compared to 2975 cubic feet for originally planted trees. In effect, planting costs were doubled to yield only 8 percent additional volume. Forest managers should avoid wasteful investments in interplanting. (925)

632. A soil herbicide treatment is needed that will eradicate dense stands of brush on upland pine sites in the South. A test with bromacil and tebuthiuron applied to hardwoods on an upland sandy loam in central Louisiana at 4, 8, and 12 pounds per

acre showed that tebuthiuron gave higher kills of most hardwood species at all rates, but was also more lethal on loblolly pines planted 12 months after than bromacil. Pine survival was lower with small pellets of tebuthiuron applied broadcast than with large pellets applied in a grid pattern. Results are of interest to researchers and to land managers attempting to develop appropriate site preparation measures for southern pinelands. (864)

633. Dicamba is not used widely as a foliar spray on hardwood brush because it is ineffective on a broad array of species. Absorption, translocation, and breakdown of the herbicide were studied with several species to help explain erratic kills. High rates of application damaged treated foliage and reduced translocation. Low rates moved freely in the plants, but were decarboxylated, complexed with sugars and amino acids, and lost from the roots into the soil. Treated plants were not killed. The greatest potential use for dicamba in foliar sprays appears to be in mixtures with other herbicides such as 2,4,5-T or picloram. (841)

634. Information on the behavior of natural hardwood regeneration on clay soil in southern bottomlands is very limited. Nuttall oak and associated hardwoods can survive under an almost complete forest canopy for as long as 15 years. Many will respond to release after 9 or more years in the understory. Sprouts and advanced reproduction of green ash, particularly, will grow from 30 to 50 percent faster in height than Nuttall oak seedlings. Dominant trees of faster-growing species may have to be killed if Nuttall oaks are to be favored. Managers can use these findings for wise selection of silvicultural systems. (857)

635. Effective and inexpensive methods are needed to thin pole-size hardwoods and control undesirable hardwoods. In tests in northern Arkansas, Tordon 101 and 2,4-D were injected into a large number of hardwood species during the dormant and growing seasons. Both chemicals were effective when applied to all test species but red maple, ash, and dogwood during season. Tordon was generally more effective than 2, 4-D and tended to cause crown kill sooner after dormant season application. These results will help land managers determine effective methods of hardwood vegetation control to meet specific objectives. (854)

#### Animal damage

636. Deer use is known to be associated with clearcutting practices in the coastal Douglas-fir forests, but the period of deer influence in these clearcuts hasn't been known. A study of 1- to 10-year-old clearcuts in these forests indicated that deer use peaks shortly after logging and declines thereafter. High levels of deer use were associated with reduced height growth and stocking of Douglas-fir regeneration, but moderate use appeared to have little adverse impact on the trees. This information helps wildlife managers and foresters adjust their management practices to meet mutually agreeable objectives. (792)

637. Little is known concerning the impact of animal depredations on direct-seeded black cherry in the southern Appalachians. Depredation of spot-seeded black cherry proved light and spotty in a series of trials repeated for 3 years in 10 cutover stands on the Cumberland Plateau. Protective screens increased seedspot stocking to 90 percent over the 81 percent obtained with unprotected seeds. Foresters and landowners can seed



black cherry in this region using nonrepellent treated seed with expensive screen protection. (799)

### Growth requirements

638. Forest managers have lacked guidelines for dealing with the complex of insects associated with forest residues. Recommendations have now been synthesized from published information and operational experience, tailored for specific pest problems and land management situations, and compiled in one reference. The forester now has advice on how to manage residues to avoid pest problems. (526)

639. Engelmann spruce has been difficult to regenerate in its harsh subalpine environment, and physiological clues may help explain and overcome this problem. In recent research, water stress in spruce seedling roots and shoots was affected by soil temperature and net radiation. For example, at soil temperatures of 10° to 15°C, xylem pressure potential of spruce stood at about -10 bars, while at soil temperatures of 0 to 5°C, the potentials decreased sharply to -20 bars, even though adequate soil moisture was available. Xylem pressure potential was correlated with net radiation only when soil temperature was above 7°C. This study provides a better understanding of how environmental factors effect water stress in spruce and provide a basis for further study of spruce physiology. (775)

640. To study root initiation in forest trees, we need to develop stabilization techniques to overcome rapid losses of enzyme activity and ways to determine the amount of protein hydrolysis. A method was discovered for alleviating decay of dehydrogenase activity in crude extracts by partially removing the phenolics and chemically reducing the quinones. A new method of measuring protein hydrolysis using radioactive iodine [125I] is also faster and more sensitive. Previously difficult or impossible experiments with protein hydrolysis and dehydrogenases can now be performed. (770,772)

641. The usefulness of the wood of Douglas-fir and lodgepole pine depends on the variation in wood density within the annual rings. A new interpretation of the actual variation of specific gravity with growth rings was derived by comparing both X-ray and densitometric equipment and light microscope equipment. X-ray densitometry was confirmed to be the most rapid and efficient method of assessing wood quality. (766)

642. Forest management recommendations can generally be more complete when we understand the physiological phenomena that are operating. Although diameter growth in sugar maple increased with thinning, the foliar nutrient concentration decreased. The decrease is attributed to dilution. Fertilized trees generally had higher nutrient concentrations but they did not grow any more. These results suggest that release sugar maple poles will grow rapidly with foliar nutrient concentrations lower than those considered optimum for species in the Northeast. (869)

643. To understand wood formation, it is necessary to study the development of primary and secondary vascular systems. Analysis of serial microsections in *Populus* shows that the primary system is organized in a precise and predictable pattern. Procambial stands arise from older leaf traces below and develop toward the apex. Subsidiary trace bundles, which then develop downward from the base primordium, are the earliest progenitors of wood formation. Vessels arise within the base of a developing leaf and differentiate as metaxylem vessels in the

primary body and as secondary vessels in each of its three traces. The structural vessel system that develops downward in the stem under the influence of a developing leaf will later serve that leaf as a functional water-conducting system. (778,779)

644. To understand the development of leaves in cottonwood, we need to know what happens to the major chemical fractions of the photosynthate in both young and mature leaves. For cottonwood leaves, the relative importance of imported photosynthate decreases as the leaf matures. There is considerable compartmentalization of imported and local photosynthate that varies with the stage of development. The precise physiological development that occurs in cottonwood leaves also helps in understanding wood formation. (767)

645. Few data exist on the growth and development of natural green ash stands on which to base silvicultural recommendations. In the Georgia Piedmont, green ash occurs naturally in pure, even-aged stands on poorly drained, silty flats. Total basal area carrying capacity on these sites is about 160 sq. ft. per acre. Volume growth averaging 39 to 65 cu. ft. per acre per year is primarily related to stand age. The pioneer nature of green ash indicates it is adapted for plantation management systems or natural regeneration or clearcut areas. (826)

646. Reduction of the spruce-fir forests of the southern Appalachians by 1920 stimulated research to find coniferous species that would grow well on the cutover land. Among 18 exotic and two local species planted on the slopes of Clingman's Peak from 1923 through 1931, Norway spruce, red spruce, and red pine have best survival, height, diameter, form, and vigor. The results also indicated that reforestation with silver fir and Japanese larch may have an important place in reestablishing the forests of the southern Appalachians. (787)

647. Unsatisfactory growth of yellow-poplar seedlings on many Cumberland Plateau forest sites in Tennessee has been attributed to recurrent soil water deficits during the growing season. Yellow-poplar seedling growth was inhibited at soil moisture tensions less than 15 bars, the permanent wilting point for most soils. Height growth was reduced, root development was drastically inhibited, and the seedlings wilted when tensions averaged 4 bars. Soil moisture content below 20 percent of available water is likely to be inadequate for newly planted yellow-poplar seedlings. Researchers and tree planters attempting to match species and site can benefit from these data. (780)

648. Poor control of substrate moisture levels has been reported to be a major contributing factor to variations in germination test results. Seven levels of substrate moisture were tested on seeds of four spruce species at the Eastern Tree Seed Laboratory in Georgia. All four spruce species proved tolerant of a wide range of moisture levels between 23 and 88 percent of the waterholding capacity of cellulose wadding. This information will help define optimum testing conditions and provide more uniformity between laboratories. (918)

649. Little is known of the relationships between water stress and cambial activity in southern pines. A study of 2-year-old loblolly pines in southern Arkansas showed that tracheid production was slower, fewer latewood cells formed, and latewood comprised less of the annual ring under simulated drought than under low soil moisture stress. The onset of latewood cell production, which occurred in early July, was little influenced by water stress. Trends in wood formation at the base of the live crown were similar to those at breast height but were less well



defined. This information is valuable to scientists studying the basic physiology of wood formation. (783)

650. For regenerating upland hardwoods, we need information on establishment and growth of trees following various cutting methods. In a study involving removal of overstory, species composition following cutting was not closely related to cutting intensity. On the other hand, subsequent height growth was strongly affected by cutting intensity with greatest growth on the clearcuts. Some difficulties associated with regeneration of oak after heavy harvest cuttings may be related to the relationship between time of budbreak and canopy removal (see 302). (781)

651. Growth regulation in plants has been hampered by a lack of knowledge concerning whether IAA oxidase activity arose from a separate or multifunction enzyme. Research evaluation revealed that IAA oxidase activity is one function of a dual catalytic enzyme. Optimum assay conditions were found using criteria of maximum initial velocity of oxygen consumption together with the optima for pH, p-coumaric acid, and hydrogen peroxide. These developments have international significance in growth-regulation research. (769)

652. Selection of Douglas-fir for various climatic regimes depends in part on the understanding of the phenology of budburst in the spring. Results from a study showed that under natural flushing conditions, date of bud burst is mainly a function of spring temperature, but occasionally also influenced by winter chilling and photoperiod. Development of these interrelationships in quantitative models would guide greenhouse operations for optimizing seedling growth and for predicting effects of seed transfer. (764)

653. The control of cambial activity and wood cell differentiation by growth hormones is not well understood. An isolated stem-segment culture technique was used in studying that control. When stem segments of *Pinus silvestris* were perfused with a defined culture medium under sterile conditions, their cambia produced new cells for as long as 15 weeks. With this technique, segments can be sacrificed at any time and studied anatomically. Effects of auxins, other hormones, and metabolites also can be studied in a controlled, isolated system. (790,791)

654. Many organisms, including trees, exhibit biological rhythms of nearly invariant periods and show well defined structural patterns of near uniform distances between repeated features. A possible explanation for this, based on biophysical and mathematical interpretation of extensive studies of the cellular basis and wave characteristics of variously "figured" woods, is advanced. A model system is proposed in which morphogenic waves of varying lengths, but similar periods, interact to form standing wave envelopes that serve as a basis of morphogenic maps. These maps are seen as underlying both patterns and rhythms in organisms. This idea is of wide theoretical interest. (774)

655. The vegetative reproduction of desirable lines of trees by means of cell cultures and embryoid formation is of great potential value. *Pinus gerardiana* cells continuously cultured in a liquid suspension system grew into callus masses when plated onto agar medium under specific conditions. When the callus was transferred to agar media supplemented with coconut water and hormonal substances, some root and shoot primordia differentiated. Extension of these techniques may lead to new methods of propagating pine asexually. (776)

## Growth and yield

656. Determining management strategies for understocked stands has been among the most difficult decisions facing foresters. A stepwise process has been worked out for attacking this problem which includes describing the stand condition, determining the cause of understocking, and estimating and comparing costs and benefits of remedial actions. Utilization of this procedure can lead to sound decisions—maximizing timber production and other social benefits—on understocked areas by fitting uses to site capabilities. (932)

657. Stand development data for virgin forests are needed as benchmarks to compare stand changes over time without map's influence. Ten periodic inventories of an unburned virgin tract of southwestern ponderosa pine near Flagstaff, Ariz., have yielded growth and mortality data on more than 3,000 trees. Fifty years of change on this 80-acre tract are documented by: (1) Individual tree records, (2) 2.5-acre subplot summaries of basal area and tree count, and (3) composite stand and stock tables. This information should be useful in modeling stand development and also as a data source for research and teaching. (916)

658. Managed stand yield tables are needed for specified combinations of site quality, frequency, intensity of thinning, and utilization standards in the spruce-fir forests of the central Rockies. Procedures for computing the wood yields of managed even-aged stands of spruce—fir, as well as information needed to determine the influence of timber management practices on other forest resources, are now available. The new procedures enable the land manager to examine probable results of his operations in spruce-fir stands, study the effects, and make necessary changes before starting the operation. (915)

659. Assessing the growth potential of a young plantation is a necessary first step when deciding whether to invest time and resources in intensive culture. Site index predictions (height at age 25 years) for plantations between 5 and 13 years of age may be in error by more than 6.5 feet for one-third of the plantations, but should be within 5 feet for two-thirds of the plantations older than 13 years. Graphs are presented that can be used by the walnut manager to determine site index for young plantations on shallow floodplain soils and on deep floodplain or upland soils. (929)

660. What is the growth and yield potential for European black alder interplanted with black walnut? In a study on a good site in southern Illinois, European alder produced 3-1/2 tons of dry matter per acre per year during the first 9 years. Dimension parts sawn from 6-foot bolts 9 to 12 inches d.i.b. at large end compared favorably with other hardwood species. If spacing and planting time of the European alder can be adjusted so that it does not overtop the walnut, it may be a useful interplanting species. (931)

661. If the age of an individual tree in a group of even-aged oaks differs by 4 or more years from the mean age of the rest of the trees, errors in measured site index occur. Younger, shorter trees tend to grow faster in height than older surrounding trees, and older, taller trees tend to grow slower than younger surrounding trees. All trees grew about the same in height when heights were equal. Measured site indexes using such age-deviant trees were in error by about 1 foot for each 3 years of age deviation. Application of this correction factor will result in more accurate determination of site index for oaks. (930)

662. Repetitive determinations of site index from conventional curves or tables is time consuming and subject to error. Formulas for computing site index have been derived from recently published site index tables for black, white, and scarlet oak in Missouri. Using these formulas, site indexes for large numbers of trees can be computed quickly and accurately by an electronic computer. (933)

663. The growth and yield of natural stands of slash pine can be altered greatly by thinning, and forest managers have difficulty choosing the thinning regime best suited for their particular stands and management objectives. A technique developed using previously published data compares growth and yield of slash pine stands on various site indices and at various ages for different thinning regimes at varying density levels. Total yield at rotation end is presented for all trees as pulpwood and as multiple products—board feet, slabs and edgings, kerf, and cordwood. The examples presented can be used in developing management programs based on product objectives and methods of operation. (919)

664. There are no published data that compare yields from seeded stands with yields from comparable planted stands. At age 22 years, average d.b.h., basal areas, and cubic volumes of plantation loblolly pine in Louisiana were slightly lower in the seeded stands than in planted stands. Statistical comparisons could not be made, however, because the plantations were not replicated. Despite the small advantage in growth and yield planted pines had over seeded pines, these results show that direct seeding is a reliable and profitable alternative to planting. (825)

665. Silage sycamore offers an opportunity to reduce rotation age and possibly increase yields of fiber for pulpwood. Sycamore cuttings were planted at  $2 \times 5$  foot and  $4 \times 5$  foot spacings in highly productive alluvium and harvested on 1-, 2-, 3-, and 4-year cycles. Yields were highest from plantings spaced  $2 \times 5$  feet apart and from harvests at 2, 3, and 4 years. Growers in the Midsouth can increase yields from coppice sycamore by reducing spacing within rows, realizing that costs of establishment may offset this advantage. (926)

666. Information on the relationship of diameter and volume growth to initial spacing in cottonwood plantations on Mississippi River alluvium is lacking. Cubic volume growth in unthinned 10-year-old plantings in Mississippi varied from 2.8 to 3.4 cords per acre per year where initial spacings were  $4 \times 9$ ,  $8 \times 9$ ,  $12 \times 12$ , and  $16 \times 18$  feet. Two thinning treatments did not increase yield. Average diameter increased as spacing increased. These findings will be valuable to foresters in selecting an initial spacing, evaluating the need for and timing of thinnings and prunings, and predicting volume production over time to meet specific management objectives. (927)

667. Little is known about the effects on tree survival and growth of careless cultivation that leaves covered and broken sprouts in cottonwood plantations along the lower Mississippi River. Covering cuttings with soil and breaking new sprouts from cuttings during early cultivation reduced survival by 30 to 70 percent. Undamaged surviving trees grew 30 to 100 percent more during the first year than those covered and/or broken. Cottonwood growers now have a measure of the importance of careful cultivation. (794)

## Forest measurements

668. Rings in aspen wood are difficult to count and measure accurately. This operation can be made easier by first making a smooth shaved surface, then oven drying for 48 hours at  $100^{\circ}\text{C}$ , and finally moistening the surface with a 4 percent solution of pentachlorophenol wood preservative in either kerosene or mineral spirits. With this technique, even very narrow rings can be seen under a binocular microscope. (949)

669. Experimental work in the crowns for forest trees can now be done cheaper and safer with an inexpensive crown-access apparatus developed on the Fort Valley Experimental Forest. The versatile rig is stable, durable, quickly moved from tree to tree, and easily removed from the truck. Although designed specifically for making nondestructive inspections of flower and conelet development and cone collection, the platform without ladder is also useful. (943)

670. Stocking standards for assessing forest regeneration in the western forest regions often have been set as an arbitrary combination of plot size and management policy. A stocking scale has been developed to evaluate several stocking goals while using a single plot size. The new stocking scale should facilitate more rational assessment of forest regeneration establishment. (947)

671. Growth patterns are poorly described for many tree species, and there is a continuing need for accurate site index curves and yield tables. A comprehensive handbook has been prepared which presents step-by-step instructions for tree stem analyses. It details field procedures and computer analyses which provide stem profiles, height-age graphs, and cards and data lists for conifers up to 800 years of age. These instructions enhance the usefulness of the stem analysis research method in obtaining growth information and will be a valuable reference for forest managers. (941)

672. More efficient procedures are needed for handling stem analyses for obtaining growth information from old-growth forests. A stem analysis procedure has been developed that includes special techniques needed for old-growth trees in the high-elevation mixed forests of the Cascade Range in Oregon and Washington. A supporting computer program analyzes data and provides graphic and tabular tree descriptions. These provide the basis for site index curves and individual tree volume growth estimates in old-growth forests. (941)

673. Many reported tests of accuracy of instruments used to measure trees are worthless because, without real knowledge of measurement accuracy, no evaluation of instrument costs and benefits is possible. Only results of repeated measurements by trained observers give valid estimates of measurement error. Measurement studies in the Pacific Northwest show that tests should include basic instrumental and observer accuracy under easy measuring conditions, and then progress to the forest where accuracy is more difficult because of impaired visibility. These evaluations help those involved in forest measurements to recognize types of measurement error with optical instruments, biases, and related measurement theory. (937)

674. There are unanswered questions worldwide about the adequacy of techniques used to evaluate newly-established stands. Tree seedlings need to be inventoried one or more times during the regeneration period to determine if reforestation efforts have been successful. This review raises questions that should be resolved regarding objective evaluation procedures



for setting stocking standards, making allowances for tree losses in developing stands, and developing intensity levels for field sampling. (948)

675. Measurements with optical calipers and rangefinder dendrometers may not be too meaningful if the tree is out-of-round or viewed from one direction. Cross-section measurements of a large sample of felled coastal Douglas-fir trees revealed that out-of-roundness was greatest at stump height. The longest diameter at any height in the tree was randomly oriented on moderate and steep slopes, and only slightly related to direction or slope. Out-of-roundness is not likely to bias volume estimates in large-scale cruises, but individual tree bias can be appreciable. Managers dependent on accurate volume estimates should consider this information in tree analysis work. (950)

676. Increased aspen utilization by tree-length and whole-tree harvesting and weight scaling have created a demand for methods to estimate volumes and weights of whole trees and stands. From data collected in the Lake States, tables have been developed which estimate gross volume, green weight, and dry weight for individual trees, diameter classes, and entire stands. Weight scaling will improve utilization of aspen in north United States. (946)

677. Years and sometimes decades must pass before the effects of specific management practices can be measured as changes in yield. Simulation modeling provides a useful alternative to waiting for results. A model which was developed to estimate production of loblolly pine plantations based upon synthesis of data on input, cycling, and loss of nitrogen indicated that the cycling rate was a critical area in need of further research. The model can also be used to predict effects of cultural practices such as thinning, harvesting, fertilization and burning on the distribution of nitrogen in the system and on plantation productivity. (956)

678. Foresters have continued to make wide use of the site index curves in USDA Miscellaneous Publication 50 but until recently they were generally forced to make laborious graphic determinations from these curves. A FORTRAN program has now been written which utilizes recently fitted site index equations for the four major southern pines to compute site index (or height) arrays for any given index age and arrays of integer age and height (or site index). This program will facilitate use of these curves and benefit activities ranging from operational management planning to growth and yield research analyses. (939)

679. Estimation of stem volume in standing trees is one of the fundamental problems of forest mensuration. In recent comparisons of measurements with two dendrometers, volumes obtained from Spiegel Relaskop measurements were only 1.6 percent higher than those based on Barr and Stroud measurements. The relaskop is more efficient for timber cruising because it is compact, relatively inexpensive, and reads directly, thereby lessening the chance of a reading error. The Barr and Stroud is recommended for precise measurement of diameter and volume increment. Foresters can select the instrument best suited to meet specific objectives. (951)

680. To make decisions concerning ecosystem management, we need to know how much organic matter can be safely harvested as a crop. To make estimates of the timber fraction of ecosystem production, a system was developed using a matrix of primary units of measure. The primary matrix is a set of values

for volume, bole surface, and length arrayed by top diameter of stem segments and aggregated from the largest to the smallest. The system can be used to describe and compare differences among forest stands. (934)

681. The kinds of information and capabilities needed to develop management plans for large acreages of wildland are becoming increasingly diverse and complex. A large scale Wildland Resource Information System (WRIS) has been developed for this purpose in California. WRIS is a computerized production tool for collecting, processing, storing, retrieving, updating, and displaying geographic data. The system can be useful in integrating and making the most of resource information under the manager's control. (944,945)

### Management planning

682. Northern hardwood all-age forest growth is difficult to predict and methods to use growth data for practical situations have been met with difficulty. Using data from the Upper Peninsula Experimental Forest in Michigan, a series of differential equations was developed. The equations distribute growth by size class and growth components, with resulting tables which are useable directly by forest managers. (954)

683. When faced with interpretation of complex sets of data involving large numbers of interrelated variables about which there is little *a priori* knowledge, a system called principal component analysis (PCA) offers help. The system was recently field tested with data from white spruce and red pine provenance trials in the North Carolina region. Some of the advantages of PCA included: (1) Reduction of the number of variables by deletion of extraneous variables; (2) ordination of variables as an aid to the interpretation of multivariable data; and (3) to supplement regression analysis for the identification of biological variables for further experimentation. (953)

684. Spacing of planted trees is one of the more important decisions land managers face. Measurements of 15-year-old loblolly plantings in the Piedmont of South Carolina show that more total volume was produced at spacings of  $6 \times 6$  and  $8 \times 8$  feet than at  $10 \times 10$  and  $12 \times 12$  feet, but that the wider spacings produced trees of larger diameter. Product objective and the probability of thinning should be considered before selecting the spacing for loblolly pine plantations on productive Piedmont sites. (917)

685. Some current thinning practices should be changed. Often, slash pine plantations grown on 25- to 30-year pulpwood rotations are thinned at about age 15 because of seemingly high basal areas, but no thinning or thinning a few years before the intersection of the current and mean annual growth curves would have produced more pulpwood. Maximum production of sawtimber in rotations of 35 years and under is obtained by removing pulpwood in a thinning at about age 20 and carrying only 200 to 300 trees to final harvest. To maximize board foot yields in rotations of 40 or more years, heavier stocking should be carried, with two or three thinnings before final harvest. These guides should maximize production of pulpwood and of large wood products for slash and other pine species. (920)

686. No available information compares yields from plantations of northern conifers with those from naturally regenerated aspen. Yields at age 40 compared in central Minnesota showed volumes were highest for red pine (408 cubic meters and 147 tonnes per hectare), progressively less for aspen, jack pine, and



white spruce, and lowest for black spruce (183 cubic meters and 70 tonnes per hectare). Land managers may anticipate similar variation in yields attributable to species when reforesting similar sites. (957)

#### Naval stores

687. The prospect of substituting oleoresins for petrochemicals as sources of energy prompts testing the potential of conifers for paraquat-induced lightwood production. Tests showed that oleoresin yields from loblolly pine may exceed even those of slash and longleaf pine, thereby adding millions of forested acres to the potential land base for lightwood. Eastern hemlock showed only minimal resin soaking in response to treatment. The potential for lightwood production can influence a land manager's selection of species and later management decisions. (1032)

688. Two systems of producing lightwood oleoresin appear to be financially attractive with southern pines—a single wound treatment to produce lightered pulpwood trees for kraft pulping, and a multiple wound system to concentrate oleoresin in the lower bole for solvent extraction on pre-extraction of pulpwood chips. On the basis of present biological and economic information, it is virtually certain that the lightwood technique will be highly profitable, and, consequently, oleoresin production in the South may be expected to increase dramatically. (1037)

689. Chipping slash pine for production of gum naval stores generally reduces rates of volume growth. Slash pines chipped 8 years had less inside bark volume and slightly thicker bark than trees chipped 2 years, yet their d.b.h.'s were similar. Standard volume tables would not detect differences in volume inside bark. Changes in family mean tree volumes in response to chipping were only slightly correlated with amounts of gum produced. Several high gum-yielding families showed little or no reduction in volume. Reduction in volume may be a response to wounding independent of gum yield. If response to wounding is heritable, it might be possible to select trees for both gum yield and volume production. (1031)

690. If gum naval stores is to survive as a viable industry, it must mechanize and reduce labor costs. Too much labor is consumed in handchipping faces to induce resin flow. A power tool developed at the Southeastern Forest Experiment Station in Olustee, Fla., not only does the job better than by hand, it is much quicker and consequently cheaper. A virtually identical tool is proving its worth in chemical inducement of lightwood. In both uses, this tool will help relieve energy shortages by increasing oleoresin production. (1030,1033,1036)

691. Oleoresin increases caused by chemically induced lightering are difficult and costly to assay because of erratic, nonhomogeneous lightwood formation in the bole. Research in northern Florida showed that oleoresin content cannot be adequately determined using specific gravity differences between treated and untreated portions of slash pine stems. Chemical analysis revealed that oleoresins are measurably increased beyond areas of visible lightwood. These findings were most useful in determining the sampling intensities required and in devising new analytical techniques to attain necessary accuracy in oleoresin yield estimates. (1035)

## BREEDING IMPROVED TREES

### Inherent variation

692. Since genetic variation is associated with geographic distribution, seed zones need to be delineated to prevent off-site planting problems. To accomplish this in the Great Plains, the region was divided into 86 seed collection zones on the basis of soil, topography, water, and climate. Future provenance tests will be used to determine needs for adjustments in zone boundaries. By following these guides, land managers should be able to better prevent disastrous losses caused by genetically maladapted seed. (965)

693. Browsing of Douglas-fir, resulting in reduced height growth and stocking levels of Douglas-fir regeneration, is a serious silvicultural problem in the northwestern U.S. coastal forests. Studies in Oregon and Washington indicate that animal browsing activities are related to tree genotype, that there is a positive association of foliar chlorogenic acid content with susceptibility to browsing, that levels of this acid were heritable, that foliage of browse-resistant classes of Douglas-fir emitted greater amounts of volatile terpenes than that from susceptible genotypes, and that terpene levels and composition are heritable. All of these findings have application in breeding Douglas-fir for resistance to browsing. (798)

694. To increase efficiency in tree breeding programs, it is desirable to be able to predict performance at a later growth stage with data from nursery results. Until these correlations are computed, there is no certainty that this can be accomplished. In slash and loblolly pine, correlations between nursery and 5-year heights were low and nonsignificant. Genetic gains made through progeny testing depend on establishment of field plantations. (979)

695. Although Tamarack has potential for short rotation pulpwood in the Lake States, adequate information on which seed source should be used is lacking. Results from studies in Wisconsin indicate that growth gains are possible through proper seed source selection. Sources that grew well on one site also grew well on another, indicating little genotype x environment interactions. Increased production can result through proper seed source selection. (974)

696. Yellow birch is a valuable hardwood species that occurs over a wide geographic area. To identify superior individual trees and the seed source that will produce the fastest growing and best quality trees, provenance and progeny tests were established in Wisconsin, Michigan, New York, and New Brunswick. Northern sources tend to survive better than southern sources when planted in the more severe northern climates. There was no direct relationship between growth and latitude of seed origin, but some sources grew faster than others. Thus growth gains can be made in future breeding work through individual tree and seed source selection. (962,963)

697. To get the fastest growth and good stem form in black walnut plantations we need to determine the best geographic source of seed. In a southern Indiana plantation, trees originating south of the planting site were generally larger and had greater straight height than trees from the north. Trees from stands in North Carolina, Tennessee, and Kentucky should be included in walnut improvement programs for southern Indiana. (961)

698. In improvement programs involving black walnut, maximum gain depends on knowing the amount of variation, inter-

trait correlations, and gain obtainable by different selection methods. In a young plantation in southern Illinois, family selection for height, diameter, or straight height resulted in gain for all three of these traits, with a slight genetic loss for date of leaf flush. Family selection gave greater expected genetic gain than either provenance or mass selection. Black walnut seed orchard developers in eastern U.S. can use this information to help increase the future supply of high quality walnuts. (977)

699. Although black walnut trees grow rapidly on good sites, no strains have been selected for droughty sites. In a greenhouse test, seedlings from western Missouri and Kansas generally did not wilt as quickly as did those from southern Illinois and Kentucky, but in field tests, there were no differences in survival and growth between the western and eastern trees. In the future, black walnut selection work for drought hardiness should explore local and south-of-local sources. (960)

700. Although sulfate naval stores recovery is a highly profitable part of modern pulping practices, little is known about what gains might be expected through genetic selection. Wood samples from 20 wind-pollinated loblolly pine families showed that there were large differences in yields for ethanol-benzene extractions and turpentine. Trees that have large limbs and are rust-infected tended to have higher yields. Results will be useful in making marketing decisions and breeding plans. (969)

701. The discovery that paraquat can induce resin-soaking in slash pine is of interest to tree breeders because of the possibility that the response may be genetically controlled. In a test in Florida, 20 clones of slash pine treated with paraquat yielded more oleoresin than did the control. Although the extent of resin-soaking varied highly among clones, it was not correlated with gum naval stores yield of the ortets. Genetic selection for paraquat response would yield little or no gain. (988)

702. Although jack pine has been shown to be well-adapted to Nebraska conditions, growth and other traits are highly variable—probably due to seed source of planting stock. So a study was established to determine which seed origins were best adapted for use in Nebraska and the Plains. Survival of trees from all 28 geographic origins tested was good, and height growth for sources varied from 7.6 to 14.3 feet, with southern sources generally taller. The taller sources also have the best form and are recommended for planting in the central Plains. (985, 987)

704. While ponderosa pine is native to and has been used extensively on the Great Plains for many years, performance of planted trees has not always been consistent. Six-year survival and growth data from a 78 origin provenance test in east-central Kansas indicates that growth is better from lower elevation sources. A seed collection area in north-central Nebraska and adjoining South Dakota is recommended for Kansas. (966)

705. Conifer species that will survive and grow are needed for establishing plantations on the Great Plains. Species with potential for good survival and growth need to be studied for provenance variation. In eastern Nebraska, an 11-year-old study of 52 rangewide seed sources of red pine revealed that there were height differences among provenances. A fast-growing origin from Quebec is recommended, and seed supplies are being acquired to improve plantings in eastern Nebraska. (986)

706. As planting and intensive culture of *Populus* clones becomes more widespread, the physical and chemical properties of the wood become increasingly important in clonal selection. In a

study of 18 *Populus* hybrid clones in Wisconsin, the percentage of lignin and wood sugar, specific gravity, and growth ring width varied widely. Growth rate did not affect the chemical composition of the wood. And, it appears that clones can be selected combining rapid growth and desirable chemical composition traits. (967,1320)

707. Progeny testing of hardwood tree species has been limited and associated problems have been unique. A summary of papers dealing with progeny testing problems is presented in Proceedings of IUFRO Working Party on Progeny Testing. Researchers and tree improvement personnel can use this to increase efficiency in their tree improvement programs. (970)

708. Seed yield is a vitally important factor in getting genetically improved stock into plantations. In a 9-year study of slash pines, conelet and cone yields showed a weak tendency to increase with increasing d.b.h., tree height, percentage of live crown, and tree age. Rainfall in June stimulated conelet production the following spring. Temperature did not affect yields. Previous fecundity was the best indicator of a tree's capacity to produce conelets, cones, or seed. Number of seed per cone was not related to cone yields per tree or percentage of sound seed. These results will aid seed orchard managers in increasing seed production as well as researchers in directing new research efforts. (992)

709. To increase the growth of loblolly pine in the South, silvicultural and genetic manipulation is needed. In a study in Arkansas and Louisiana, simple selection of large seedlings in the nursery bed resulted in larger trees at age 9. Even greater gains can be expected by carefully choosing the parents. In loblolly pine at age 10, average volumes of wind-pollinated plus-tree progenies exceeded those of woods run progeny by 18 percent. Additional gains can also be made through proper geographic seed source selection. These results will influence management decisions concerning investments in tree improvement. (971,972,973)

710. Virginia pine is a valuable and desirable source of pulpwood in the southern United States, and information on potential for genetic improvement is needed. A study in Virginia indicates that total wood mass in 8-year-old trees is subject to only minor genetic influence. Although there were differences in nutrient concentration, most of this was environmental rather than genetic. Tree improvement programs can now be adjusted to anticipate the low expected gains. (980,983)

### Insect-disease resistance

711. To quantify genetic gains in slash pine, it is necessary to compare progeny from selected and average parent trees. After 15 years of evaluation for survival, growth, and rust resistance, it is apparent that mass selection is an effective method for improving slash pine in Georgia. Individual selections from the best families will now be used as sources of material for advanced generation breeding, leading to still further genetic increases for slash pine in the south and southeastern U.S. (1003,1004)

712. To increase production in southern pines, methods are needed to reduce losses from fusiform rust disease, and, at the same time, maintain or increase growth. Hybridization looks promising for accomplishing this goal. Gains have been made by crossing high rust resistant shortleaf pine with the more rapid growing loblolly, followed by backcrossing and selection. For



further gains, future southern pine breeders need to establish more plantations of shortleaf x loblolly pine hybrids. (999)

713. Subjective estimates of mortality from prescribed burning for control of brown-spot needle blight are seldom reliable for making preburn surveys of infected longleaf pine seedlings. Results from a test fire in Alabama recommended burning when the average infection level on crop seedlings reaches 20 percent and the root collar diameters are between 0.3 and 0.7 inches for grass-stage and more than 1.5 inches for height-growth seedlings. This information will help schedule prescribed fires more effectively for mass selection of superior and disease-resistant seedlings and improve the vigor of newly regenerated stands. (1000)

714. Seed production from southern pine seed orchards is not fulfilling expectations. Female flowers of both slash and loblolly pine often die during the period from just before the flowers become receptive to about 3 weeks after pollination. Preliminary experiments in which loblolly pine flowers were inoculated with fungi isolated from damaged flowers of slash pine produced damage symptoms on the loblolly pine flowers. If damaging fungi can be identified and control measures found, benefits will accrue to southern pine seed orchard programs throughout the South and Southeast. (1002)

715. Genetic improvement of loblolly and slash pines depends on selection of strains that are resistant to fusiform rust. Loblolly pine from Livingston Parish, Louisiana, has been shown to be resistant and has grown well in central Mississippi, Alabama, and Georgia. Resistant trees can now be identified in artificially inoculated progeny tests, but because there is genetic diversity in the fungus, it is important to test trees against an array of inocula. Reliable resistant breeding programs and improved trees will result from this work. (995,996,1005,1007)

#### Tree breeding methodology

716. Geneticists use pollination for controlled breeding in tree improvement, but, since the pollinating season is short, a rapid procedure is needed. A simple and inexpensive pollinator was designed which is compact, waterproof, non-clogging, and requires only small quantities of pollen. This device has considerably increased the speed and ease of pollinating. (1008)

717. Self-pollination in seed orchards can result in seedlings with reduced vigor and steps should be taken to minimize selfing where it is a serious problem. In a slash pine seed orchard in Georgia, the occurrence of selfing, as estimated by chlorophyll mutants, was low and is not considered a serious problem. Gains from tree breeding efforts can be made without significant loss due to selfing. (976)

718. In developing genetically improved forest trees, we commonly use data for traits measured at only a single time, e.g., at age 25. However, we do not know if this is the most efficient approach. The form of the height growth curve as a composite trait was subjected to genetic analysis, with tobacco as an example. The results show that selection for whole growth curve functions is more effective than for size at a series of ages. To make maximum gains, tree breeders should consider economic growth functions as selection criteria, instead of size at one age. (1025)

719. Many ponderosa pine seedlings grown in California nurseries are too small to survive field planting. One approach to improving this situation is to collect seed only from parent trees proven to produce large seedlings. Wind pollinated families from

stands selected in a variety of environments in the northern Sierra Nevada showed large within-stand differences. By nursery testing seed trees, and excluding seed from the poor performers in future years, there can be immediate gains in the size of planting stock and improvement of nursery efficiency. (1022)

720. For action programs of walnut genetic improvement to be effective, sound procedures for design and evaluation of superior trees are needed. As a result of many tests and much more experience workable procedures for evaluating selections have now been established. Tree improvement specialists in States, industry, and the National Forest System can benefit from the use of these new guides. (1010)

721. Maximum genetic improvement in black walnut is dependent on having correct estimates of environmental and genetic variation. By use of walnut twins (derived by splitting germinating seeds), efficient estimates of variation for growth and phenological traits were obtained. Almost all genetic variation was due to additive gene action, and family selection is recommended for walnut improvement programs in eastern U.S. (978,1023)

722. Black walnut trees usually grow very little the first year after transplanting. In a southern Illinois study, limiting environments were much more critical than genotypes in explaining the characteristic lack of first-year growth. Greater gains can be made by emphasizing site selection and amelioration than by attempting to breed trees that can withstand transplant shock. (1011)

723. Predicting genetic gain in tree improvement programs requires unbiased estimates of heritability. The correlation coefficient, used as an estimator of heritability, has biases in it which are related to number of trees per family and the coefficient of relationship among family members. Methods and tables have been developed to devise adjusted estimates based on number of trees per family and degree of selfing. (989,1015)

724. High soil fertility and good soil physical condition are required in pine seed orchards. Irrigation increased tree growth during the first 7 years; however, neither irrigation nor fertilization had a significant effect on tree size at age 12. A hairy indigo cover crop increased soil nitrogen about 250 pounds per acre during the first 5 years but did not increase tree growth. After the legume was shaded out, at about the 6th year, soil nitrogen began to decline and tree growth showed an increase on the cover-cropped plots compared to plots which were disked. Soil improvement by nitrogen fixation can possibly substitute for nitrogen fertilization. (1027)

725. Grafted seed orchards of lodgepole pine have been plagued by graft incompatibility losses. Anatomical evaluation showed that incompatible grafts had greatly reduced xylem growth in union zones. The internal incompatibility symptoms were correlated with scion overgrowth and needle chlorosis and could therefore be rogued, thus affording a considerable dollar savings in grafted seed orchards. (1012)

726. Identification and classification of deviate phenotypes would be useful in studies where gene markers are needed. In a comparison of isoenzyme characteristics in Douglas-fir, dwarfs were unique in that they had some bands not found in normal trees, some bands stain darker, and some bands were missing. The zymograms furnish a useful means for chemically identifying dwarf variants, which may be used in studying pollen flight. (1013)



727. In genetics studies, it is sometimes necessary to store tree seed which segregates at germination for mutant markers. It is necessary that the mutant seed maintain its viability in long-time storage for as long as normal seed to provide original segregation ratios. Agricultural literature indicates that storage often selectively kills some mutants. However, an albino mutant used in experimental studies in Douglas-fir was found to store well for 6 years. (1029)

728. Graft rejection is a major problem in Douglas-fir seed orchards and will continue to be until highly graft-compatible rootstocks are available for general use. Improved laboratory methods have been developed for testing compatibility of Douglas-fir in the Pacific Northwest. Incompatibility can be studied and recognized and an efficient laboratory method for preparing stem sections has been devised and described in a new guide. (1018)

729. Casting acrylamide gel columns for electrophoresis usually requires depositing a water layer over gel solutions to achieve clean, flat surfaces. To offset attendant inefficiencies, a technique employing flatground disposable plungers was developed. The system reduces cost as well as expedites the many electrophoretic assays necessary for studying the genetic structure of plant populations. (1020)

730. Techniques for propagating select trees by rooting are needed for establishment of seed orchards. A new technique involving stem girdling and hormone treatment apparently forces accumulation of food reserves and callousing and has led to increased rooting success in slash pine. Multiplying clonal lines of improved trees for seed orchards and plantations is now possible. (1021)

731. Southern pine seed orchards frequently are fertilized to increase and maintain productivity, but questions persist concerning formulation and timing of application. Nitrogenous fertilizers proved most stimulatory to production of strobili and cones on young loblolly pine grafts in seed orchard tests in Mississippi with ammonium nitrate giving the best response. Mid- to late-summer applications quadrupled seed production. Such findings provide valuable guidelines for seed orchard managers. (1026)

732. When mating designs are complex or unbalanced, estimates of combining ability are difficult for the practical plant breeder. A FORTRAN computer program was recently prepared to show how general combining ability values from cross-, open-, and self-pollinated progeny can be derived from a single analysis. Using this program, more efficient analyses are possible. (1028)

## IMPROVING USES AND PROTECTION OF WOOD

### Utilization potential and processing of wood

733. A comprehensive summary of current information on bonding wood into dependable, long-lasting products is presented. Characteristics of wood that affect gluing are detailed, as well as types of adhesives and processes used for various conditions. This definitive source of information on adhesive bonding is useful to all the forest industries concerned with gluing of wood. (1304)

734. The assurance of long-term durability of plywood adhesives requires service testing over long time periods. A rate-process analysis method has been devised to evaluate, over shorter times, the long-range durability of several adhesives for Douglas-fir and yellow birch plywood. Using the short-term predictive test, it is concluded that the differences among adhesives, when in service environments, are due largely to their relative resistance to moisture rather than to their thermal instability. The methods described can be beneficial in selecting adhesive substrate combinations suitable for long-term structural performance. (1251)

735. The glue line of a glued wood product can be greatly weakened by damage incurred on the wood surfaces during machining and surface preparation. Crushed and torn wood cells break away easily when the glue line is stressed. Sawing damages surface cells more than knife-cutting. Planing or jointing produce stronger cell surfaces. Sharper tools cause less surface damage which again will result in stronger glued products. (1294)

736. Wooden houses should be repainted only after previous paint has weathered thin because paint failures tend to occur if the paint film is too thick. A simple test is described for determining whether an old paint surface will form a satisfactory bond with latex paint. Simplified instructions for repainting a house, including preparations of surface and application of paint, are included. This information is of broad interest to owners of homes and other wood structures. (1283)

737. Early selection of desirable genetic strains of trees is difficult because of the long times required to firmly establish characteristics of growth and wood quality. Aspen tissue, grown in the laboratory on synthetic medium, has been treated with growth hormones and the resulting effects on growth rate and cell characteristics observed. The associated changes in enzyme activity are quantitatively related to growth-rate, confirming the feasibility of using the measurement of enzyme activity for assessing growth rate and wood quality characteristics. Reliable early prediction of growth rate can aid geneticists in their selections of desirable strains of trees. (1313)

738. One alternative for improving the yield of solid wood from a log is to slice thick lumber with a knife (similar to veneer cutting) thereby eliminating sawdust. The effects of 17 different slicing process variables that have been determined are summarized. Guidelines are provided which will assist machine manufacturers in the design of a commercial thick slicer. (1287)

739. New forming and pressing techniques are required to make shaped structural products from reconstituted wood. The technique holding most promise for commercial production of an I-beam type shape maintains a level mat during the forming period by utilizing a low bulk density fibrous material for the web portion of the beam and aligned flakes with high bulk density for the flange areas. Physical properties depend strongly on beam configuration and indicate that with proper engineering design and construction techniques, beams can be made to suit a variety of structural applications. (1249)

740. Forest residues provide a large potential raw material source amounting to nearly 9.5 billion cu. ft. annually. High quality structural particleboard can be manufactured from forest residues containing as much as 8 percent bark and 12 percent decayed wood. Manipulating processing techniques and particle alignment techniques allows a variety of performance specifica-

tions to be met. These studies are important in gaining acceptance of particleboards made from forest residues for structural uses. (1250,1305,1370)

741. Producers of hard maple have difficulty in consistently drying it to the normal light orange-yellow or white color desired for most products. The wood often tends to darken during drying. Research findings relate color development with variations in dry-kiln conditions. Colored material within the ray and axial parenchyma cells is related to the different discoloration types. Recommendation of drying procedures are presented which helps avoid dark coloration and the unnecessary waste of high quality hardwood. (1278,1279)

742. Common drying practices "overdry" most of the lumber in order to reduce the moisture content of the wettest boards to 19 percent, the maximum allowed by American Lumber Standards. The technological basis for an improved two-stage moisture equalizing treatment is provided. The first stage keeps the driest lumber from becoming too dry while continuing rapid drying of the wettest pieces. In the second stage, moisture is restored to the surfaces of the driest boards, while the wettest boards continue to dry. The use of recommended drying schedules can greatly reduce the costly losses during machining caused by excessive drying. (1280)

743. Southern pine sites usually have a substantial amount of small-diameter hardwoods mixed in with the primary pine species. Certain properties of the common hardwoods were determined in order to facilitate more extensive utilization of the hardwood biomass. Moisture contents of the wood and bark varied from roughly 50 to 150 percent. In most species, stemwood moisture was higher than branchwood and branch-bark moisture higher than stem-bark. Moisture reduces longitudinal permeability of the hardwoods. Ratios of the much greater longitudinal permeabilities to the lesser radial and tangential permeabilities were quantified. (1240,1241,1273,1258)

744. It is generally agreed that railroads of the Nation must expand their capabilities to contribute to the national good. Consequently, they must also substantially increase their rate of tie renewals if roadbeds are to be maintained in acceptable condition. While larger trees are becoming more scarce, faster trains and heavier loads will require that mainline ties average the large 7- by 9-inch size now in common use and larger. A logical source of wood for these ties is the enormous inventory of underutilized small hardwoods in the South, East, and Midwest. The process of dowel-lamination can permit manufacture of 7- by 9-inch mainline ties by laminating together two smaller pieces from logs with small-end diameters of only 8.3 inches—a size that is plentiful. The concept should be of value to the railroads, to suppliers of crossties, and to woodland managers. (1257)

745. Wood processing plants—though net consumers of energy—often have available sufficient quantities of green bark and wood waste fuel to make themselves relatively self-sufficient in energy; the problem lies in developing an adequate technology for economically burning such wet fuels. A process has been developed and described whereby green bark residual from southern pine lumber production can be direct-fired in a low-cost suspension burner and the heat used to kiln-dry lumber. The invention will substantially aid the industry to become self-sufficient in energy and at the same time solve a residue disposal problem. (1260)

746. Southern pine lumber—particularly that cut from small logs—tends to warp excessively when kiln-dried to the moisture content at which most of it is used (about 9 percent M.C.). A kiln apparatus has been developed for continuously producing dry lumber that is free from crook, bow, and twist. The kiln employs paired arrays of rolls in combination with rigid lumber-guiding and warp-restraining bars in such manner that lumber is totally restrained against warp as it moves continuously through the kiln. Through application of the principles embodied in this invention, losses attributable to warp in southern pine lumber can be largely eliminated. (1261,1262)

747. The preponderance of trees harvested in the U.S. in the future will be too small to yield lumber in long, wide, thick pieces. A method for producing multi-ply lumber from rotary-peeled veneers has been developed and patented. The system can supply structural lumber of virtually any length and width from logs of 4- to 8-foot length and diameters as small as 7 inches. The system involves gluing-up veneer plys with the grains aligned parallel. The yield of salable lumber product from logs is nearly 50 percent greater than the yield obtainable by conventional sawing processes. (1263)

748. For every cubic foot of pine on southern pine sites, there is about 0.8 foot of hardwoods. The hardwoods are often not utilized. The shaping-lathe headrig can be a key to utilizing these small, mixed hardwoods for pallets and lumber. The flakes formed by the lathe are suitable for structural particleboard, molded products, or pulp. Using mixed hardwood flakes from the shaping-lathe headrig, a structural exterior flakeboard was developed that is intended to be competitive with sheathing plywood. The shaping-lathe headrig is now a commercial reality. Much of the heretofore unutilized southern hardwoods now can become a commercial asset and be added to the timber inventory. (1259,1264)

749. In the years ahead, expanding kraft pulpmills in the South will have difficulty in harvesting sufficient wood to satisfy their requirements without major increases in the price of wood. A technological development that can assist in solving this supply problem is the invention of a machine that first severs lateral roots and then pulls southern pines from the ground like carrots. The machine harvests and bunches complete trees with taproot attached at a sustained rate of one to two trees per minute, thereby increasing pulpable wood volume harvested per acre by about 20 percent. Site preparation costs and hazard from beetles (and perhaps from root rots) should be substantially reduced by the new harvesting system. Dirt adhering to taproots presents a problem yet to be solved. Equipment manufacturers, procurement foresters, and land managers are benefiting from this research. (1266,1267)

750. After harvesting trees in pine plantations, logging slash is windrowed and burned. Subsequently, the site may be strip-plowed to control weed competition for new seedlings. Burning diminishes soil nutrients; skimming off top soil during the piling of slash greatly reduces fertility, and the bare soil rapidly loses moisture. A concept for site preparation is now advanced that calls for residual tops, branches, stumps, and underbrush to be hogged (cut up) by a new mobile wood-mulching machine as it slowly traverses the harvest site. Hogged material is spread as mulch between rows of planted trees via a belt system. A prototype mulcher has been built and tested. The procedure should reduce fire hazard, retain nutrients and soil moisture, suppress



weed growth, and improve regeneration and growth of new trees. (1268)

751. A common problem of the southern forest region is the underutilization of small diameter hardwoods. Medium-density fiberboard is a promising outlet for such wood, which can be supplied to mills in the form of "barky" chips. Boards of good quality can be made of small southern hardwood trees with bark included. Inclusion of bark diminishes modulus of rupture, tensile strength, and modulus of elasticity, but these effects can be countered by altering pressing schedules. The results of this study will be used by the fiberboard industry. (1310,1314)

752. The large volumes of forest residue remaining after timber harvest in the Pacific Northwest usually require treatment of some sort to meet multiple land management objectives. Over 200 guideline statements were developed by experts in various land management disciplines to help land managers apply the best technical and research knowledge in achieving these objectives. A unique keying system is provided for determining which guidelines apply to each planned management activity on a given site, within a given forest species association type. Application of these guidelines can materially improve the quality of management on both public and private forest lands. (1290)

753. Large trees that are defective or decayed are often not used even though a substantial amount of sound (usable) wood still remains. In order to economically utilize this type of tree and reduce waste, estimates of the lumber recovery that can be obtained from these large, defective, low quality trees are needed. Information on the obtainable lumber grades and volume yields will help forest-land managers, timber buyers, and timber processors more efficiently utilize this significant resource. (1308)

754. High quality hardwood lumber for the extensive furniture industry of the southeast United States is becoming more costly and more difficult to obtain. Available hardwood lumber must be used efficiently with minimal waste. Operations research has shown that the sequence of unit steps within the furniture parts manufacturing operation affected costs more than it did the efficiency of utilization of lumber.

An automated furniture parts mill has also been designed. Automation can improve the efficiency of lumber utilization by reducing decisionmaking, centralizing production of certain parts, and improving materials flow. (1232,1271)

755. Appraisals of standing trees ordinarily ignore the potential value of products such as bark, sawdust, and chippable residue produced when trees are processed into lumber at a sawmill. Estimates of these other products are important to the sawmilling industry and to people concerned with determining current timber volumes and values. Yellow poplar, longleaf pine, and shortleaf pine sawtimber trees were processed into lumber. From the sawmill data equations were developed to predict the weight of bark, sawdust, lumber (54 percent in each case), and chippable residue produced in the sawmill. This enables buyers and sellers of southern pine sawtimber to evaluate all the products they can expect to recover when processing trees through a sawmill rather than having an estimate of only lumber volume. (1242,1289,1303)

756. The geometry of the hardwood flakes going into particleboard has a profound effect on the ultimate strength properties of the board. Structural particleboards must meet rigorous strength specifications. Grain angles should be kept

parallel to the length of the flake. Knife planing across the grain (ringhead planer) produces superior hardwood flakes. Utilizing hardwood wastes to make flake boards (flakes from ringhead planer) for structural applications can help alleviate demands on high quality softwood sawtimber. (1255,1256,1309)

757. Adequate penetration of chemical is necessary to successfully treat hardwoods with preservatives, fire retardants, stabilizers, or pulping chemicals. With some woods, penetration is difficult. Mechanisms and rates for movement of various treating liquids through resistant hardwoods have been determined. A mathematical description of the relationship between wood moisture content and moisture diffusion rate is presented. A mathematical model for the penetration of organic liquids is now available and can help predict the effectiveness of potential wood treatments. Contrary to softwoods, air-drying increases the permeability of hardwoods. Surface preparation or cutting method greatly affects the subsequent permeability of the cut surface. (1239,1240,1295,1296,1298,1238)

758. New methods of drying hardwoods to reduce wood waste due to splitting and cracking and to decrease costs are important needs of the hardwood processing industry. Freezing wood prior to drying reduces splitting and cracking. Pre-soaking of wood in a solution of natural wood extractives can also be beneficial in reducing wood damage and shortening kiln-drying times. (1244,1245)

759. Bark has been an undesirable by-product and usually has been burned as waste or dumped as landfill. With increasing concerns about environmental degradation, energy needs, and fiber shortages there is a need for more information on bark properties that can lead to its increased use. Data on percent bark by volume, percent of weight of bark and wood, and percent moisture content of bark and wood were determined for quaking aspen, black spruce, jack pine, balsam fir, and balsam poplar in northern Minnesota. These data can be used to develop specifications for boilers in which bark is to be used as fuel, and to calculate transportation and processing costs. (1274)

760. Large variations in wood density and shrinkage are very troublesome to users of Hawaii's most abundant timber tree species, Eucalyptus. Intensive sampling of wood indicated both specific gravity and shrinkage increased with distance from the pith and with tree height. Within-tree variation exceeds between-tree variation, therefore, Eucalyptus lumber can be sorted by its original location in the tree into groups of much more uniform specific gravity and shrinkage, which then can be marketed by Hawaii's sawmillers as wood types suited for specific uses. (1306)

761. A COM-PLY stud (two-by-four) is a composite sandwich type of lumber with a particleboard core between two double layers of southern pine veneers. Such studs have strength and stiffness equivalent to, or superior to, solid softwood studs and are also less variable and remain straighter in use. COM-PLY studs were used to build three demonstration homes. User acceptance was very satisfactory. Composite studs can greatly extend the supply of softwoods, since small tree parts can be used for the particleboard core. Hardwoods can also be used in the particleboard core. A prototype machine has been built to incorporate fiberglass reinforcing into the studs for more demanding uses such as floor joists. (1237,1270,1380)



### Wood chemistry and fiber products

762. Wood is sometimes considered a vast new source of chemicals. The two major technical deterrents to the effective utilization of lignocellulosic residues for chemical, enzymatic, or microbial conversion processes are cellulose crystallinity and the presence of lignin. Lignin restricts enzymatic and microbial access to the cellulose. Crystallinity restricts the rate of all three modes of attack on cellulose. Practical pretreatments which can open up the lignin-carbohydrate complex and can alter the fine structure of cellulose are needed. The many physical and chemical pretreatments investigated over the years are described and critically evaluated. (1331)

763. The potential role of wood as a material base for fuels and chemicals has been reviewed. It is proposed that wood residues at forest industry mills now offer several advantages as fuels for direct burning. Wood should be used on a structural material when possible. Incineration, landfill, and wood-derived industrial chemicals seem less advantageous than direct fuel (residues) and structural applications. (1315)

764. High prices of animal feeds and predicted world population growth make it necessary to search for methods to develop new sources of protein. Forest industry residues, urban wood residues, and municipal residues have been evaluated as potential sources for the production of protein by using them as animal feeds. The lignin must be removed from wood (as in pulp mill and paper residues) before the carbohydrate fraction of the wood can be effectively utilized as an animal feed. The economic, environmental, and technical considerations in wood-for-animal-feed have been summarized and will aid in assessing the feasibility of various advanced systems to use residues in protein production. (1330)

765. The utilization of wood residues for pulpwood sometimes requires the storage of unbarked (roughwood chips) which may deteriorate at a faster rate than debarked chips. Chips from unbarked and debarked red alder logs were stored for 6 months in simulators of chip piles. For both types of chips, essentially the same large losses in wood substance, pulp yield and pulp strength were observed. However, both types of chips can be effectively preserved over the same storage time by the use of a preservative. (1339)

766. More than one fourth of the pulpwood consumed by the paper industry is derived from wood wastes in the form of chips from lumber and plywood mills. During outside storage, chips deteriorate resulting in serious losses in wood fiber and chemical (tall oil) by-products. A screening of potential preservative treatments has shown several chemical combinations to be effective in significantly reducing losses of fiber and tall oil by-products. The reduction in tall oil losses alone can recover the cost of the preservative treatment. (1337,1338,1340)

767. With present papermaking processes, the lower quality high-yield and hardwood pulps often cannot be utilized for paper products where high strength and stiffness are required. Insufficient interfiber bonding results in a low-strength paper. A new drying system substantially increases interfiber bonding in these papers by restraining fiber movements in the thickness direction during drying. The resulting paper has greatly improved performance properties that permit it to be used where high strengths are required such as linerboard for boxes. The process greatly improves the potential for utilization of hardwoods. (1335)

768. Corrugated boxes often fail because the paper components are susceptible to stresses which cause adjacent layers of fibers to separate. An improved test procedure is now available to evaluate this mode of failure. The test method was tested and applied to fiberboard and hardboard specimens. This test procedure facilitates new improvements in the important compressive strength property of fiber boxes. (1316)

769. With the gradual depletion of many common construction materials, renewable wood and paper materials will assume a more important role in the future. On a weight basis, papers can surpass the stiffness and strength of wood if fibers are highly oriented, or aligned. Basic data on fiber orientation techniques are now available that can lead to wider use and substitution of stronger paper products in construction applications. (1341)

770. Strength properties of corrugated containers made from wood pulp derived from roughwood (wood chips with bark included) have been unknown. Tests on corrugated containers prepared from Douglas-fir roughwood have demonstrated that the strength properties of the container and its component linerboard were comparable to conventional commercial products, except for compressive strength which was significantly lower. Roughwood can be used to make container linerboard. Using roughwood for manufacturing corrugated boxes can effectively extend our wood resources by substituting for higher quality pulpwood. (1322,1323)

771. Corrugated fiberboard containers are of fundamental importance to commerce and are a major paper product on a volume basis. By optimizing material (paper) design properties through the use of a new idealized, more comprehensive container model, the strength of containers can be increased without utilizing additional fiber. (1327)

772. Corrugated fiberboard containers are the largest single category of paper products going into recovery and recycling processes. The effect of repeated recycling of container fiberboard has not been known. The first recycling reduces strength properties of a subsequent container up to 35 percent (with containers made from 100 percent recycled fiber). Subsequent recyclings have a minor effect. (1326)

773. Solid waste disposal is a serious problem for many municipalities. Recovering and utilizing more waste paper could reduce the solid waste problem. Recycled newspapers can be a potential source of fiber for corrugating medium. Blending 35 percent newspaper with mixed hardwood pulp and adding 2-1/2 percent starch resulted in a corrugating medium (for box manufacture) that was approximately equal in strength with a commercial corrugating medium. The medium showed satisfactory performance. This information provides municipalities with another means of utilizing some of their solid waste and the corrugating medium industry an additional fiber source. (1328)

774. By-products of the kraft pulping process have become the dominant source of naval stores (chemicals derived from the pine tree). Naval stores chemicals can serve as substitutes for petroleum products in many applications. A comprehensive review of the potential of naval stores chemicals is newly published. Potential new sources are examined, particularly the promising area of chemically induced oleoresin production in pine. The herbicides that induce heavy oleoresin formation in southern pine do not induce it in eastern hemlock to levels with commercial potential. (1324,1343,1344)

775. The neutrals fraction comprises 5-10 percent of the chemicals found in southern pine tall oil and represents an unused raw material. Little was known about their composition. A quantitative analysis identified over 80 compounds including all those present at the 0.1 percent level or better. Sterols and diterpenes predominate. Basic information on neutrals has been needed for more efficient processing of tall oil and the characterization of the neutrals could lead to new commercial products. (1319)

776. Chemically induced resin formation (lightening) in pine pulpwood trees before harvesting increases pine resin content several fold, but could have adverse effects on pulping procedures and pulp properties. Now it is known that artificially lightened wood can be pulped without difficulty and without loss in yield or quality of pulp. There is no significant change in the relative composition of the components in the resin (resin acid, turpentine, and fatty acid fractions). If artificial lightening becomes a widespread practice, the increased yield in pulp by-product chemicals may significantly augment our petrochemical resources. (1329,1345)

777. Though high volumes of timber are available in the tropics, harvest is usually selective. Traditionally tropical forests have been skimmed of valuable species (high-grading). Greater emphasis on pulp and veneer processing that is tolerant to a variety of species is needed to permit a more complete harvest and utilization of existing trees. Correlations between wood density and tropical climatic life-zones suggest that woods with similar processing characteristics can also be correlated with climatic zones. Mixed stands can then be cut within a climatic zone and processed together. This system, along with processes tolerant to many species for the production of pulp, panel material, and/or structural timber, can help avoid high-grading and other silvicultural problems faced by managers of tropical forests. (1317)

778. The advent of whole-tree chipping has made it necessary to examine tree branches for properties that affect pulp yield and quality. Pine tree branches contain 21 to 33 percent bark; stems contain 10 to 13 percent. As branch size decreases, branchwood and branchbark specific gravity decreases and bark percentage increases. The strong and weak fiber characteristics of branch material have been quantified which makes it practical for the paper industry to predict the impact of total-tree pulping on fiber and paper quality. (1333)

779. No information is available on seasonal variation in weight of short-rotation (4 to 6 years) sycamore under coppice management. Seasonal variations may occur because of tissue maturation and the variations could affect pulp yields and pulp properties. The average dry matter content per cubic foot of 4-year old coppice sycamore increased 8.7 percent or 2.1 lb./ft.<sup>3</sup> during the summer, remained constant during fall and winter, and decreased 3.8 percent the following spring. If the increase is caused by an increased amount of cellulosic wall material being laid down, a harvest cut later in the summer season would take advantage of the increased cellulose. (1318)

780. Among the serious waste disposal problems facing the U.S., disposal of municipal sewage sludge and wood processing residues are among the most troublesome. These wastes often coexist in the same communities and both can be beneficial for agricultural lands. One of the barriers to recycling sewage sludge as a fertilizer is that in large volume land applications, too

much nitrogen may be released into the soil, surface runoff, or ground water. Wood and bark, on the other hand, when applied to land, tend to rob the soil of nitrogen as they decompose. By mixing sludge and wood wastes, it is possible to control the amount and rate in which nitrogen is released to the soil and plants. Wheat growth can be enhanced by fertilizing with sludge-wood-bark mixtures, turning the pollution and economic problems associated with sewage sludge and wood waste disposal into an asset. (1334)

### Wood engineering

781. In some engineered applications (microwave drying), wood is subjected to varying electric fields. Data on the interaction of wood with such fields (dielectric properties) are valuable. A newly issued report catalogues these data over relatively wide ranges of important variables for design purposes, and shows the data to be consistent with a physically plausible theoretical model of wood. The data show an unexpectedly large positive interaction of frequency and moisture content, with extremely large values of dielectric constant for moist wood at low frequencies. This data is of value to manufacturers considering the use of wood as electrical insulators. (1358)

782. Underutilized eastern hardwoods represent a potential resource for meeting future wood fiber demands. A compendium of information on the mechanical properties of 23 hardwood species provides a key to their extended utilization. A method is also described for utilizing hardwoods in structural applications (beams and rafters) where building codes (and other regulatory authority) do not prohibit their use. (1346)

783. In the design of wood structures, design parameters are established on the basis of the analysis of component units (rafters, walls) rather than on a total integrated structure. By racking a complete wood-frame structure, the strength of the total structure was determined. Conventional wood framing provides excellent strength. Under severe stresses, floor-to-wall connections failed first. Other tests show that moisture gradients in roof joists can cause bowing and subsequent separation of interior ceiling from wall. Such weaknesses can easily be rectified with minor design changes. (1388,1389)

784. Timber bridges are widely used in rural areas and on Forest Service roads. They are durable, economically attractive, and can be erected with a minimum of skilled labor and equipment. The newly developed glued-laminated bridge deck provides excellent structural performance, and promises to extend the service life of the bridge by protecting the superstructure. An efficient construction procedure is presented, and suggestions made to avoid common pitfalls. (1387)

785. Single and multi-family wood-frame dwellings which are outmoded or in a deteriorating condition exist in communities throughout the country. Many of these homes could be rehabilitated at a lower cost than new construction and with much less material than a new home. To promote the twofold advantage of lower cost houses and conservation of our natural resources, a guide was developed for appraising the suitability of woodframe dwellings and to serve as a guide for rehabilitation. It includes information on examining a house to determine its suitability for rehabilitation, the consideration of esthetic values, planning for improvements to be made, and details for accomplishing the rehabilitation. It should be useful to homeowners, lending institutions, and contractors. (1382,1383)



786. The degree to which sound is transmitted through partitions and throughout a structure is an important factor in structural adequacy. Wood-frame and wood-based panels are good sound insulators. Correlations between field tests and lab tests of the insulation value of wall components have been described. Sandwich construction type panels alone do not give adequate sound insulation. An auxiliary wall added to a conventional stud and gypsum board wall can provide adequate sound insulation in the resulting partition. These factors are important to architects, loan agencies, builders, code agencies, and others interested in maintaining privacy in multifamily dwellings. (1360,1361,1362,-1363)

787. There are no standard test methods available for evaluating the impact behavior of plywood and particleboard sheathing alone. The feasibility of testing a small panel over a single span with the joists fully supported and the effect of panel size and edge condition were investigated. A reliable test method was developed for evaluating the sheathing. This makes possible realistic evaluations of new sheathing materials such as particleboard panels made from ordinary tree harvesting wastes or hardwood plywoods. Results will be useful to code and standards groups, sheathing manufacturers, and other researchers in the structures field. (1385)

788. Shipping pallets consume more than 14 percent of the Nation's annual timber supply. Longer-lasting pallets can aid in conserving lumber. Pallets last longer when forklift trucks are equipped with specially fabricated "impact panels" that distribute the stresses on pallet deckboards when they are rammed by the forklift during pick-up. The nails used in pallet manufacture are largely imported. The use of available, sufficiently effective U.S.-made staples could reduce dependence of domestic pallet producers on foreign nail sources. Using 2 1/2-inch-long plastic-coated staples, pallets made with about one-third more staples yield equivalent performance to nailed pallets and are cost-equivalent. This information is helpful to all pallet producers and users seeking an alternate supply of pallet fasteners. (1365,1384)

789. Shipping pallet decks are ordinarily made of solid wood boards. Boards could be replaced in some cases by decks made of recycled fiber, if performance is found to be satisfactory. The performances of pallets made with five experimental medium-density hardboard decks were compared with performances of similar pallets made with decks of commercial particleboard, plywood, and knife-cut veneer. The results showed that equivalent performance is produced by pallet decks of thicker medium-density hardboard, and this capability could help to reduce the expected shortage of pallet component material. (1366)

790. New engineering data on difficult-to-evaluate structural components has been developed. Particleboard specimens were evaluated at different rates of loading in bending, tension, and shear. This data will be used to develop reliable design criteria for particleboard. The properties of hardboard-webbed I-beams were experimentally evaluated and compared to known engineering theories. Beam behavior under short-term loading can be reasonably well predicted from fundamental engineering theory. (1371,1386)

791. Wood fiber from urban residues such as wastepapers, discarded pallets, dismantled railroad cars, and diseased elm trees has potential use in wood-base particleboard panel products such as medium-density board materials for furniture core

stock. Dry-formed, medium-density hardboards have been made from various combinations of these residues. Most of the properties of the boards are as good as those required for mat-formed particleboard, but they were not as good as properties of commercial dry-formed, hardboards. This information will be useful for potential producers and consumers of these materials and to municipalities considering the use of wood fiber waste for making panel products. (1367)

792. Fire safety regulatory agencies recognize certain inadequacies in the methods and procedures used for defining "non-combustible" materials. A potentially improved method based on "rate of heat release" of a material has been developed. Information on rate of heat release for typical wood-base building materials subjected to fire exposure (certain plywoods, hardboard, lumber products, insulation board and particleboard) has been developed. Results are important to regulatory officials, researchers, and material producers. (1348)

793. A knowledge of fire endurance characteristics of structural sandwich panels is necessary if acceptance criteria are to be established for use in single family and other housing construction. Tests conducted on both sandwich panels and wood-frame wall panels provide performance data on panels with and without chemicals to extend fire resistance times. Treating wood building materials with sodium dichromate will reduce the amount of smoke generated under certain flaming and non-flaming conditions. (1349,1351)

794. Automatic lumber grading machines help ensure that the highest potential use is made of the timber harvested. A prototype stress-wave lumber grading machine was developed. The control and computing function for this machine is designed around a micro-processor system. Successful use of this micro-processor system will encourage similar versatile and reliable control systems in the wood products industry. (1350,1369)

795. Due to current interest in history of the Nation, a description is provided of procedures used in building a plantation house that was constructed in 1796 in central Louisiana. Reliance was almost exclusively on local materials. Though French tradition and culture predominated in Louisiana, carpenters' tools of English design seem to have been favored. (1379)

796. The ends of heavy timber beams exposed to the weather are subjected to large changes in moisture content that cause checking, degradation of finishes, and the danger of decay. Finishes, flashings, and other protective covers may be used to minimize weathering effects, and recommendations based upon observations of past designs and current exposure experiments are offered. These recommendations are of value to architects and builders. (1375)

797. The shortage of high-quality hardwood timber, coupled with general price increase, has resulted in the need for a means of accurately estimating quality in the standing tree. A tree grading system that is directly related to predicted lumber grade yields has been developed. Application of the system requires the measurement of diameter and merchantable height, and the estimation of defects. Lumber grade yields are available by tree grade and size for the following species: yellow and paper birch, red and sugar maple, black cherry, yellow-poplar, basswood, and northern red, black, white, and chestnut oak. The lumber grade yields enable timber buyers and sellers to estimate the value of graded trees. The grading system may also serve as



the basis for stratifying tree quality during a forest inventory. (1356)

### Prevention and Control of Wood-destroying Organisms

798. Immediate utilization of loblolly pine logs infested with southern pine beetles is nearly impossible with today's processing techniques. In Maryland, the economic feasibility of water spray storage was tested as a means of saving such logs for use as piling and sawlogs, 1 to 2 years after their beetle infestations had passed. Results after 15 months of storage indicate that tree-length logs can be stored with little or no net cost to yard operators. Spray-storage of piling-class logs was more profitable than storage of sawlogs due to a slight benefit from increased penetration of creosote into the heartwood. Forest managers and timber users can now increase the use of beetle-infested logs through better storage techniques. (523)

799. Laboratory studies with subterranean termites require a uniform diet of known constituents upon which the termites can survive and reproduce as well as on wood. A diet that contained 34.06 percent alpha cellulose, 65.87 percent water, 0.06 percent sterol, and 0.01 percent methyl-p-hydroxybenzoate met these requirements. For the sterol ingredient, both B-sitosterol and ergosterol were superior to cholesterol. This diet will (a) eliminate the use of a wood diet with its widely varying chemical composition, (b) allow more accurate measurement of experimental variables, and (c) serve to accelerate control-related research on subterranean termites. (527)

800. Better knowledge of natural toxic or repellent substances in wood may become the basis for the development of new methods for termite control. The survival of the Formosan subterranean termite was studied on sawdusts, solvent extracted sawdusts, and absorbent paper pads treated with extracts prepared from 23 species of resistant tropical hardwoods. Termites could not survive on absorbent paper pads treated with extracts from 14 woods. These results will serve as the basis for isolating termiticidal substances from these 14 woods and determine their utility as termite repellents or toxicants. (524)

801. Many houses are constructed with built-in errors that will predispose them to damage by wood-decay fungi, termites, or other wood-destroying insects. Fifteen percent of all owners of houses built after 1969 in one county bordering the Gulf Coast reported wood damage in their homes due to these agents. Most of this damage could easily have been prevented. A method of inspection that focuses attention on quality control within samples of houses, rather than an inspection program that requires a superficial examination of all houses under construction, is proposed for consideration by members of the Southern Building Code Congress. (525)

802. The toxic chemicals added to wood in conventional preservative treatments are a source of environmental concern. By modifying the chemical structure of wood with non-toxic alkylene oxide derivatives, it becomes resistant to fungal attack and less likely to swell, shrink, or warp. A model is presented as a guide for the selection of conditions and chemicals for effective treatments. This treated material is suitable for a variety of products such as flooring, window units, and tool handles. (1300,1301)

803. Except for the naturally durable wood species such as redwood and black locust, the service life of wooden pilings,

poles, and fence posts is often limited by decay associated with moist wood conditions. Preservative treatments can reduce or prevent decay, greatly extend service life, and result in an economic market for many small trees and thinnings as posts. A broad program of in-place, long-term testing of potential preservatives and preservative systems used on various species is demonstrating the degree of effectiveness of preservative treatments and expected service life of treated posts. Tests sites are located in Mississippi, Alabama, Louisiana, Florida, Georgia, Tennessee, Maryland, New York, Wisconsin, South Dakota, Illinois, Missouri, Nebraska, Colorado, Montana, Hawaii, and Panama. (1252,1253,1254,1275)

804. Knowledge of physiological mechanisms which enable fungi to decompose wood is important if we want to prevent decay or to utilize these organisms in industrial processes. A physiological explanation of how brown-rot fungi rot wood suggests that the peroxide-iron system of the fungi might be used to treat cellulosic material for industrial use. Phenolic or iron-chelating compounds which may be produced by nondecaying isolates of decaying species may offer possibilities as a prepulping treatment. (1269)

## MARKETING UNDER-USED SPECIES AND RESIDUES

805. To quantify logging residues, a reliable and efficient sampling method was needed. The line intersect method was tested in Appalachian hardwoods and found to provide accurate estimates of volume in cubic feet per acre. A computer program was prepared to process large amounts of data in a short time. Thus, land managers can transform field measurements into useful summaries with minimum effort, and can adequately estimate volumes of hardwood logging residue using the highly efficient line intersect method. (1159,1160,1162)

806. To anticipate logging residue conditions that are likely to exist after a selection cut, the forester needs a means of predicting residue amounts from individual sawtimber-sized trees. An equation was developed using data from 36 mixed oaks in southwestern Virginia. Dbh, bole length, and sawlog height are used to predict gross volume in cubic feet for each tree marked for cutting. The sum of individual tree volumes can then be converted to a per-acre or stand basis. The forester now has one more planning aid that can be used to evaluate alternatives before harvesting and utilization decisions are actually made. (1161)

807. Railroads are spending millions of dollars annually to dispose of old ties that might otherwise be converted into useful industrial fuel. Studies of crosstie weights revealed that the average old crosstie weighs about 190 pounds. On a national basis, about 2 million tons of old crossties are available for use each year. Studies of fuel values revealed that 1 ton of old ties has the equivalent heat of about 100 gallons of No. 2 fuel oil or 1/2-ton of bituminous coal. Nationally, the use of old crossties could replace the annual consumption of 4 1/2 million barrels of imported oil. Income from the sale of these old ties could be channeled into the purchase of new ties to improve deteriorated roadbeds. Thus, the lagging forest economy would be enhanced by this marketing venture. (1153,1154)

808. Markets are needed for low-grade Appalachian hardwood logs. An evaluation of plywood made from combinations of

Appalachian species found that 16 different species combinations will meet PS 1-66 standard. Because of the species mixture in Appalachian forests, the most likely combinations for commercial production would consist of red oak, hickory, and hard maple outerplies with yellow-poplar, soft maple, and black gum innerplies. Development of a hardwood plywood industry in the Appalachians would expand markets for low-grade timber and help extend the Nation's softwood timber resource. (1155)

809. Hardwood bark is an effective amendment for improving the physical structure of soils used in horticultural containers. Different shredding processes may influence the availability of bark-absorbed water. This study determined the effectiveness of bark as a water reservoir for plants. The results will be useful in further research to develop improved horticultural growing media. (1163)

810. Sawmill operators and other primary wood processors are in need of commercial uses and markets for large quantities of bark. The highway market for mulch for revegetating disturbed soils offers a large potential market for this material. All species of bark are suitable for revegetative mulching, and the fibrous and bulky nature of bark make it unnecessary to use asphalt or other binders to hold it in place. This study describes the requirements for bark mulch for both seeding and planting, the estimated market potential for 26 eastern States, and provides bark producers with guidelines for entering the market. (1158)

811. In the United States, sawdust has been burned for fuel mostly in individual boilers, special home-heating furnaces, and as reconstituted fireplace logs. A report describes how to construct and use a practical, low-cost sawdust stove for heating cabins or workshop areas. Such stoves, in common use in other parts of the world, can be used to heat a room 20 feet square for 6-10 hours without tending. (1164)

812. Because of rapid inflation in fossil fuel prices and severe problems in nuclear-power programs, wood has been suggested as a primary fuel for steam-electric plants. The estimated total 1970 volume of unused lumber and plywood mill residues and logging residues (in pieces above 4 inches in diameter) would have been sufficient to meet about 10 percent of the annual fuel requirements for U.S. steam-electric plants. Costs of collecting, transporting, and preprocessing logging residues probably were too high for such materials to be competitive with coal in most regions, even at average 1974 coal prices. Use of waste bark and wood as fuel by forest products plants, however, appears highly advantageous and will limit the availability of mill residues to commercial steam-electric plants. (1156,1157)

813. Potential market outlets for forest residues include use for particleboard, historically the most rapidly growing sector of the wood products industry. Resource, investment, market, and locational factors are likely to influence further development of the particleboard industry in the northern Rocky Mountain area. Results indicate that expansion will be located close to mill wastes until this source is exhausted. As mill wastes become scarce, plants will be designed to make use of forest residues. The report provides a basis for evaluating probable utilization trends in particleboard, and a broad economic analysis from which more specific plant feasibility analyses can be made. (1166,1167)

## SUPPLY, DEMAND, AND PRICE ANALYSIS

814. Although expenditures for U.S. highway construction increased about 2 1/2 times from 1954 to 1972, the use of wood products in this industry remained nearly constant during the period. Even so, annual use ranged from 400- to 500-million board feet. This level of use is likely to continue, but expected shortages and higher costs of materials from nonrenewable resources may make wood more attractive and competitive for highway construction use. This study provides details of types of wood used, and other information useful to wood products suppliers interested in the market. (1173)

815. Indiana's business community needs information about the black walnut timber resource situation. A new report describes the resource, its economic importance, and long-run outlook for increasing supplies of quality timber for benefit of persons interested in growing black walnut in Indiana. (1184)

816. Recent unfavorable economic conditions and changing long-run demographic factors have called into question the realism of past projections of long-run housing demand. This study examines the effects of demographic change and alternative economic policies on long-run housing requirements. New housing projections are provided for alternative levels of long-run economic growth. These should prove helpful in examining the current long-run outlook for housing construction and forest products requirements. (1174)

817. The mobile home industry is a major user of forest products. Information on industry consumption is essential to accurate analyses of total demand for timber products. Georgia leads the Nation in production of mobile homes. The average mobile home built in Georgia in 1973 used 1,982 bd. ft. of lumber, 1,009 sq. ft. of hardwood plywood (3/8-inch basis), 812 sq. ft. particleboard (3/4-inch basis), 255 sq. ft. of softwood plywood (3/8-inch basis), and only 33 sq. ft. of hardboard (1/8-inch basis). The increased use of lumber—334 more bd. ft. than in 1970—was attributed mostly to increased strength requirements in the State's construction code. The construction of larger single-wide units and more double-wide units was an important factor in the use of large quantities of hardwood plywood and particleboard. With the emphasis on larger mobile home units, the mobile home industry provides most of the new low cost housing for Georgia while using large quantities of lumber, hardwood plywood, and particleboard. (1169)

818. The insulation board, hardboard, and particleboard industries have greatly increased production with consequent larger consumption of wood raw materials. Medium-density fiberboard (MDF), whose classification as a hardboard or separate product is currently under much discussion, represents a blend of processes and raw materials used by the particleboard and hardboard industries. By 1980, production of MDF board is estimated to be 1 billion sq. ft. (3/4-inch basis). An even newer product is thin particleboard. It was estimated that 147 million sq. ft. (3/4-inch basis) of this board was manufactured in 1973. In the long run, the woodbase fiber and particle panel industries will have a competitive advantage over many other wood products industries because of their ability to use underutilized raw materials such as low quality roundwood and wood residue of both hardwood and softwood species. (1170)



819. One requirement for long-range timber forecasts is to ascertain the probable impact of technological change on the consumption of stumpage. This paper proposes a measure of technological change for the lumber and wood-products industry. The findings indicate that technology was advancing at an average rate of 1.75 percent per year between 1949 and 1970. Such findings improve our ability to predict the consumption of stumpage and to formulate policies relative to our forest resources. (1177)

820. A recent publication describes the essentials of futures trading with respect to lumber, presents a few examples of how the industry might benefit from this activity, and explores the trading potential of different segments of the industry. Results show that this marketing tool can help the industry to forward-price, minimize its inventory risk, earn a carrying charge on its inventory, and enlarge its inventory financing. The strongest trading potential exists among large firms producing, distributing, and using western lumber items. Southern pine lumber producers, distributors, and users do not have as strong an incentive for hedging as their western counterparts. (1178)

821. Public policy choices in many program areas can be improved with information about prospective and feasible levels of aggregate timber supply from the Pacific Northwest. A recent study shows that significant declines in timber harvest will occur over the next 15-30 years under present harvest scheduling policies even with a higher level of management than is currently being applied. While many reforestation opportunities exist, they will not yield significant harvests within the next 15-30 years. (1172)

822. An understanding of the trade-offs between the log export and domestic timber processing industries is necessary to weigh alternative export control policies. Direct employment per thousand board feet of logs processed is higher in domestic lumber and veneer and plywood industries than in the log export industry. However, relative product values and indirect effects of domestic and export markets vary over time. Success of policies to maximize trade-offs between markets is not certain because responses of industry members to changes in policies are uncertain. (1168)

823. Current information on forest industry activities is of interest and use to timber managers, processors and users of forest products. Quarterly marketing reports on forest industries of the Northwest present up-to-date information on production, prices, employment, trade, volume and value of stumpage sold by public agencies, and other related items for Washington, Oregon, northern California and Alaska. (1179,1180,1181,1182,1183)

824. An understanding of how national economic forces affect local economies is essential for planning at the local level. Oregon's forest products industries have been squeezed between rising timber prices and declining demands for processed products. Cycles in forest products prices and employment are keyed to domestic rather than export markets. (1176)

825. After sawlogs, veneer logs, and pulpwood, wood poles are the most important end-use for industrial roundwood. Although no specific projections have been made, expansion of demands for electric and communication facilities, growing needs for utility pole replacements, and rising use of poles in construction, should result in increases in wood pole demand in the years ahead. An analysis of regional softwood timber inventories and

pole production and preservative treatment indicates that supplies of timber suitable for poles are adequate for the foreseeable future. (1171)

826. Demand for most timber products dropped sharply in 1974 and early 1975 in response to declines in activity in the principal end-use markets. However, based on trends in the fall of 1975 and an analysis of the factors expected to affect these markets in 1976, the outlook for most products is for renewed growth in production and consumption. International trade should also increase in 1976 as the economies of both the United States and its major overseas customers for wood products improve. With increased demand and consumption, prices for timber and timber products can also be expected to rise. (1175,1185)

## IMPROVED MARKETING SYSTEMS

827. Logging operators need to forecast harvesting costs for proposed timber sales if they expect to maintain a profitable business. For each logging job, they should evaluate the mix of men and machines and predict the effects on costs when changes in the system are proposed. A computer program was developed to simulate the complete harvesting sequence from standing tree to mill. The simulator is designed for Appalachian conditions, but can easily be modified for use in any region. With it, the logging manager can simulate alternative harvesting systems and examine any number of changes without incurring large capital expenses. (1202)

828. Some timber in the Appalachian Region does not have enough volume or value to warrant construction of good truck roads. However, our studies showed that off-road log haulers called forwarders could operate successfully in mountain terrain even with adverse weather and road conditions. Forwarders enable loggers to harvest timber considered unavailable because of location or cost of extraction. (1208)

829. Tandem-axle log trucks weighed in West Virginia carried so much load weight on the rear axles that maximum legal payloads could not be hauled. A logging truck design guide was developed to show loggers how to determine the correct truck wheelbase and body configuration. By using this guide, loggers can maximize truck payloads without exceeding either the manufacturer's specified axle weight capacities or the legal axle weight limits. With optimum load weight distribution, the legal payloads of the trucks sampled could be increased an average of 6,000 pounds. (1191,1192)

830. The practice of scaling hardwood sawlogs by weight has not yet become widely accepted. Millowners continue to stick scale because existing weight scaling systems are hard to start, troublesome to check, and difficult to adjust. The adjusting factor method of weight scaling eliminates these difficulties because weight per board foot conversion factors are constantly modified to cover fluctuations in sawlog characteristics. From a test of 500 truckloads of mixed hardwood logs, volume differences between adjusted weight scaling versus stick scaling were less than 3.5 percent. Adoption of the adjusting factor method could help improve working relationships between log producers and buyers through a mutually acceptable scaling practice. (1186)

831. Segments of the forest products industry have shifted from volume to weight as a base for marketing transactions. Yet



there has been no published data showing the relationship between weight and gross cubic volume for rough forest products. Data from about 4,500 Appalachian hardwood logs have been analyzed to show weight/volume ratios for prevalent species. Tables show the ratio between sawlog weight including bark and cubic sawlog volume both with and without bark. Lumbermen can use these values to determine quantities of marketable by-products such as chips, bark, and sawdust in relation to sawed lumber volumes specified by weight scaling. Researchers should find the ratios a helpful tool in developing new weight/volume mensuration techniques. (1209)

832. Air drying is too slow and erratic to permit hardwood lumber producers to meet marketing schedules and changes in market demand; it also frequently results in excessive lumber degrade losses. To help alleviate these problems, we developed a commercial-scale low temperature dryer for drying hardwoods to the "air dry" condition. The dryer utilizes solar heat to dry hardwood lumber in 1/3 to 1/4 the time and with about 1/3 the degrade losses experienced in air drying. (1195)

833. In order to increase hardwoods' share of the \$1 billion office furniture market, it is necessary to know what factors influence the selection of this type of furniture. It was found that quality, appearance, and purchase price have the most important influence on the purchase decision. Intended use and appearance were the key factors in the purchase of wooden furniture. With this knowledge, manufacturers of wooden office furniture can adjust their marketing strategies to improve the competitive position of wood. (1187)

834. The tremendous increase in pallet usage in recent years has resulted in the need to establish a pallet repair and salvage industry. Basic information on types of damage, severity, and location were determined so that pallet repair standards could be developed. With proper repair standards and efficient equipment, it was found that 92 percent of the damaged pallets could be economically repaired and reused. Establishment of an efficient pallet repair and salvage industry could greatly extend the use of our hardwood resources. (1196)

835. Softwoods and low density hardwoods have long been considered inferior for production of reusable wooden pallets. Research has shown that properly designed and constructed pallets of softwood and low density hardwood (aspen) lumber will perform as well as or better than oak pallets. Pallet production is expected to double in the next 10 years. Use of the light wood species could greatly increase the supply of raw materials for this industry. (1188,1207)

836. The cost of injury-causing accidents in the logging and sawmill industries and its impact on prices and profits has not been fully shown. A study in Central Appalachia showed these costs ranged between \$9 and \$11 million annually—not including the 40 to 50 percent of injured workers' wages that were unrecoverable. Cost estimates of injuries are a necessary step in persuading foremen and managers to insist on safe practices and accident prevention programs and equipment. (1204)

837. Members of the Christmas tree industry have limited access to published information to help solve their production and marketing problems. Lack of such information perpetuates inefficiencies in individual operations and within the industry as a whole. A bibliography was recently published and now provides a means of quickly locating the most recent information available. Use of such information will assist Christmas tree

producers, wholesalers, and retailers in making realistic decisions on production and marketing practices, and place the rurally-oriented Christmas tree industry on a stronger economic base. (1203)

838. Efficient, low cost methods of sap production are needed by the pure maple syrup industry. This study compared the traditional bucket collection system with plastic tubing and vacuum pumping and found the plastic tubing-vacuum pumping method cost less. Efficient operation, control of production costs, and acceptable profit margins are keys to successful maple syrup operations. (1201)

839. An expanding pulp and paper industry in Illinois could affect all forestry interests in the State. Current data on pulpwood marketing are needed. A study of Illinois mills shows the number and types of mills have remained stable, but pulpwood requirements have increased. Use of residues is increasing and the number of roundwood producers is declining. Price increases and competition for wood are important problems. This information is useful to other wood-using industries, forest managers, and planners in depressed areas with abundant wood resources. (1190)

840. Production and cost analyses of logging systems are needed to develop ideal timber management methods and efficient utilization systems. Complex logging systems used today are beyond the analytical ability of simple work study methods. This study describes a model of a field chipping and trucking system using computer simulation which allows a user to design and operate systems to fit unique timber and market conditions. (1193,1194)

841. The Jones Act gives British Columbia producers a transportation cost advantage over U.S. West Coast producers, and has been cited as the primary reason for the increase in lumber shipments from British Columbia to the U.S. East Coast at the expense of Pacific Northwest shipments. In the context of the total competitive environment between the two areas, however, other factors—especially stumpage price differences—may override this advantage. If exempted from the Jones Act, Pacific Northwest softwood producers would have to prepare for assembly of cargo and development of East Coast markets to take full advantage of lower-cost foreign flag vessels. Evaluation of the impact of the Jones Act should be within the context of the Act's objectives, the need for waterborne as opposed to other transportation modes, and the market forces which determine competition with British Columbia. (1189)

842. As crucial as its role is, the timber harvesting business is probably the least understood segment of the wood-using industry. An extensive survey of commercial logging in the Northeastern United States was conducted in 1974. Results provide a profile of the region's loggers and indicate practical limits to commercial logging. We found, for example, that no logging operations cut less than 3 acres or remove less than 2000 cubic feet of timber volume. Very few loggers skid more than 3/4 mile or main haul more than 100 miles to a purchase point. Results are being analyzed to discover key determinants of successful logging. (1199,1200)

843. A viable wood products industry requires that sources of materials and the identity of users be known. In a recently compiled directory, all forest products industry firms in Idaho that operated in 1973 to 1974 are identified by alphabetical listing, by

county, by product produced, and by species utilized to manufacture specified products. The directory is intended to help decision makers determine who might be affected by alternative policies, to help buyers determine who might be producing desired products, and to help industry people to indentify forms with similar interests. (1197)

844. Residential construction is the major market for soft-

wood lumber, and most lumber used in housing is in floor and wall framing. In assessing demand for lumber, it is important to know what effect changes in material and labor costs will have on the competitive position of wood and metal for framing. This study shows the comparative in-place cost of wood and aluminum framing as material and labor costs change over time. (1210)





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## WILDLIFE, RANGE, AND FISHERIES HABITAT RESEARCH

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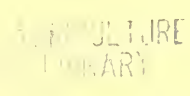








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Forest Service U.S. Department of Agriculture

Issued March 1978



# MORE FROM OUR FORESTED RESOURCES

## 1977 RESEARCH ACCOMPLISHMENTS

### FOREWORD

A major responsibility of the Forest Service is to provide scientific information to make the best use of the Nation's 1.5 billion acres of forest and related rangelands. Assisting in this endeavor are the Forest Service's eight regional Experiment Stations, and a Forest Products Laboratory. The Forest Service also conducts research cooperatively with universities and other organizations.

This report highlights some major findings coming from the research efforts of the Forest Service in 1977. It illustrates how these findings will be or are being used to obtain more benefits from forest resources. The report also includes an index of published research material for the year.

The information presented in this publication is necessarily brief. Additional information about items that interest you can be obtained from the research headquarters responsible for each reported subject. Please write these research stations directly. Their addresses are listed on the inside back cover.



JOHN R. MCGUIRE  
Chief



## Urban Forests Save Energy

Cities tend to be hotter when it's hot, colder when it's cold, and windier when it's windy than are surrounding natural areas. Researchers at the Northeastern Station have found that banks of trees—urban forests—can do a great deal to relieve these conditions. Trees can also reduce noise levels.

Preliminary research indicates that reductions in windspeed by trees around dwellings can result in fuel savings of between 10 and 25 percent. Measurements of noise and fuel use with and without trees are being continued, and recommendations are being prepared for application on Federal, State, and private lands in the Northeast.

One thing seems certain—if there are trees on a building lot before a house is constructed, it pays to keep those trees. Trees contribute as much as 12 percent to the value of suburban residential properties and as much as 25 percent to the value of unimproved building sites. Preliminary findings are that these increases in value far exceed the costs of saving trees during house construction.



A house without trees is harder to heat and cool than a house surrounded by trees.



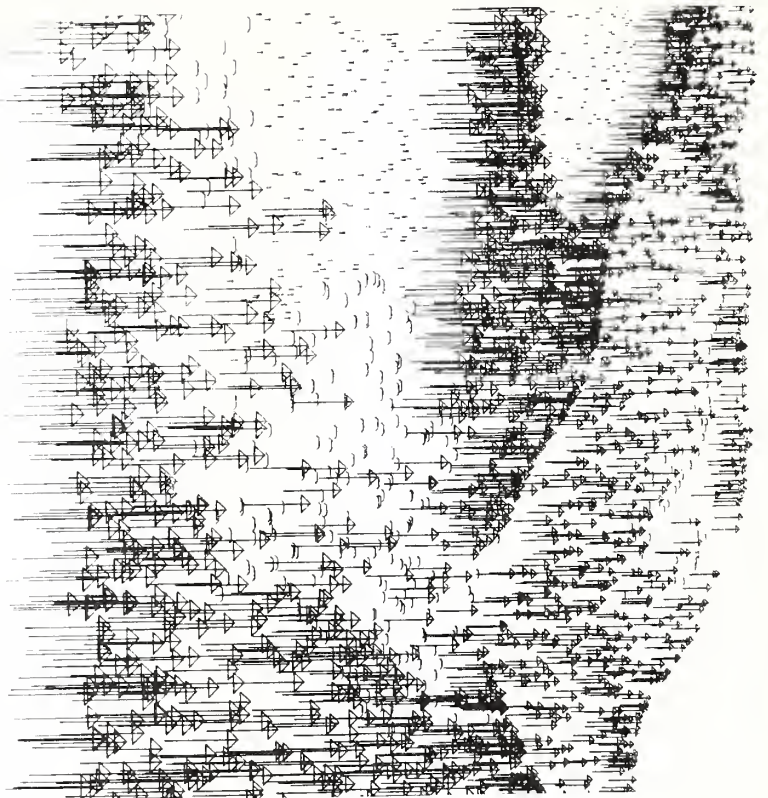
Trees also cut down on noise and increase property values.



## Visual Management

Foresters are very sensitive to the charge that they create ugliness in timber harvesting operations. They recognize the need to preserve and enhance the beauty of forest vistas. To do so, however, they need to be able to visualize the effects of major operations on the beauty of the landscape. The North-eastern Station has produced a computer program that should help.

This program, called PREVIEW, converts mapped treatments into perspective drawings that show how changes will appear from selected viewing points. PREVIEW can produce a series of drawings showing not only how an area will look immediately after a timber harvest, but also 10, 20, and 30 years hence.

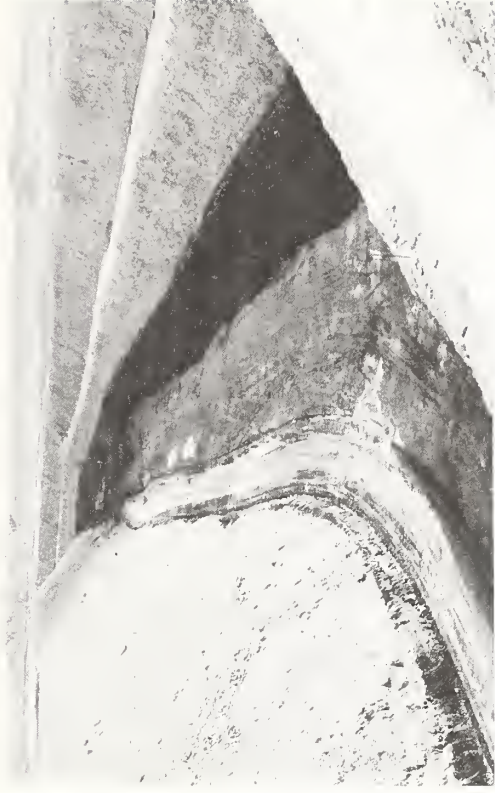


Drawings produced by PREVIEW should help foresters to estimate the visual impacts of forest treatments.

## Revegetation After Mining

The American economy depends heavily upon surface mining for minerals, and that dependence will increase as use of coal increases. Ways must be found to return lands disturbed by surface mining to productive uses. That is one goal of Forest Service research in a program called SEAM (Surface Environment And Mining). Scientists from the Northeastern, Rocky Mountain, and Intermountain Stations are contributing heavily to this program, and their research results are quite encouraging.

No single plant species or revegetation procedure will solve all the problems, because disturbed lands differ so widely. Mining occurs on areas ranging from salt-shrub desert to alpine tundra, and spoils range from toxic acid to saline. Research to date shows, however, that these conditions can be overcome. In the West, experimental plots and demonstration areas have been set up on many types of spoil and revegetation has been successful. Two of the keys to success are careful planning of mining and reclamation and a thorough knowledge of spoil characteristics.



The effects of strip mining can be minimized by getting plants established quickly on disturbed areas.





## Big Profits From Breeding Superior Trees

Investment decisions are based largely on the prospects for financial gains in both public and private forestry organizations. In public agencies, the goal is to invest public funds wisely; in private organizations, the goal is to produce profits for the owner. Forest Service economics research is designed to identify practices that will yield good returns on investments. A recently completed study in the Southern United States indicates that breeding of superior southern pines is near the head of the list of investment opportunities.

This is no pine-in-the-sky promise. Growth data for the analysis were provided by geneticists and timber management experts, and a great deal of tree improvement work is already underway. In fact, almost 200 million superior trees were planted in the South by industrial and other private landowners in the 1975-76 planting season. The analysis indicates that these landowners will reap handsome profits from their decision, and that other landowners would do well to emulate them.

Volume gains in excess of 12 percent from planting superior trees appear certain. Gains of more than 30 percent are being recorded on about one-fifth of the acres planted with superior pines. The result is an average increase of 30 percent in the present net worth of the plantations. The economists conclude that both public and private owners of large tracts will find it profitable to invest in the seed orchards, nurseries, and genetics research needed to produce superior trees.



**Investments in breeding of southern pines and in producing superior seeds in orchards will yield handsome profits.**



## Survey Techniques Improved

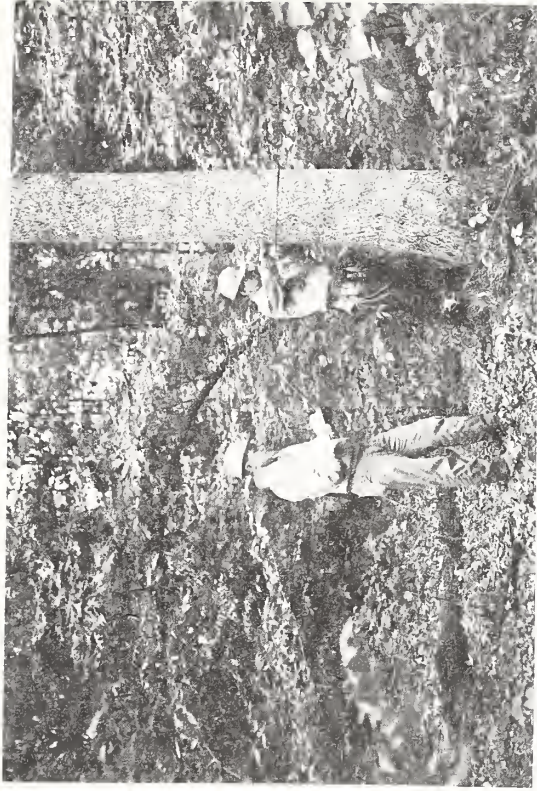
Plans and policies can be no better than the information on which they are based, and State and national forestry plans are based primarily on the information gathered in State forest surveys. These surveys have traditionally dealt primarily with timber resources, but they are now being expanded to cover other resources of the forest—water, wildlife, soils, and recreation opportunities. A research and development program has been established at the Rocky Mountain Station to improve and speed up national resource assessments. Sound techniques already in use at the Resources Evaluation Units in each Experiment Station will be included in whatever new system is devised. The primary objective is to efficiently inventory many resources in a single operation.

A technique that should improve interpretation of timber resource changes has been developed at the Southeastern Station. There resource analysts have been able to estimate volumes and acreages of timber in various age classes. This information helps show when timber can be harvested to best advantage in terms of long-term timber supplies.

A report issued in 1977 on Kentucky's forest industries showed that pulpwood production has been increasing while output of veneer logs and cooperage logs has been declining. This report is available from the Northeastern Station.

Recent changes in pulpwood production in the South have been reported by the Southern Station. The analysis shows the pulpwood production in 1976 was higher than that in 1975, but still below the record levels in 1974.

According to the North Central Station, northern pulpwood production is 22 percent lower than it was in 1974. Production has declined 12 percent or more in all but two Northeastern and North Central States.



Forest Service survey teams are adept at measuring timber volumes. They are learning how to inventory game habitat.



## A Market for Bark in Appalachia

Sawmills near large cities have been making a profit by selling tree bark to urban gardeners as a mulch. Because of their remoteness from metropolitan markets, Appalachian wood processors have not shared in this profitable business. Instead, they have had to burn or otherwise dispose of their bark. Researchers at the Northeastern Forest Experiment Station have found a solution—use the bark as mulch in revegetating soils disturbed by highway construction or strip mining.

The researchers quickly found that bark was entirely satisfactory for this purpose, if it could be spread properly. It is denser and harder to spread than cellulose fiber or straw, the materials traditionally used. They found that a mobile bark blower developed in Oregon transported and applied the bark efficiently.

Results of this research were used by an eastern manufacturer who designed a machine that spreads bark mulch, seed, and fertilizer in a single operation. This large potential market should solve a problem of bark disposal and turn a profit for Appalachian mill owners.



**Bark makes an excellent mulch for revegetating areas disturbed by highway construction, and it can be blown into place with appropriate equipment. (Photo by Stanley E. Corder, Oregon State University)**

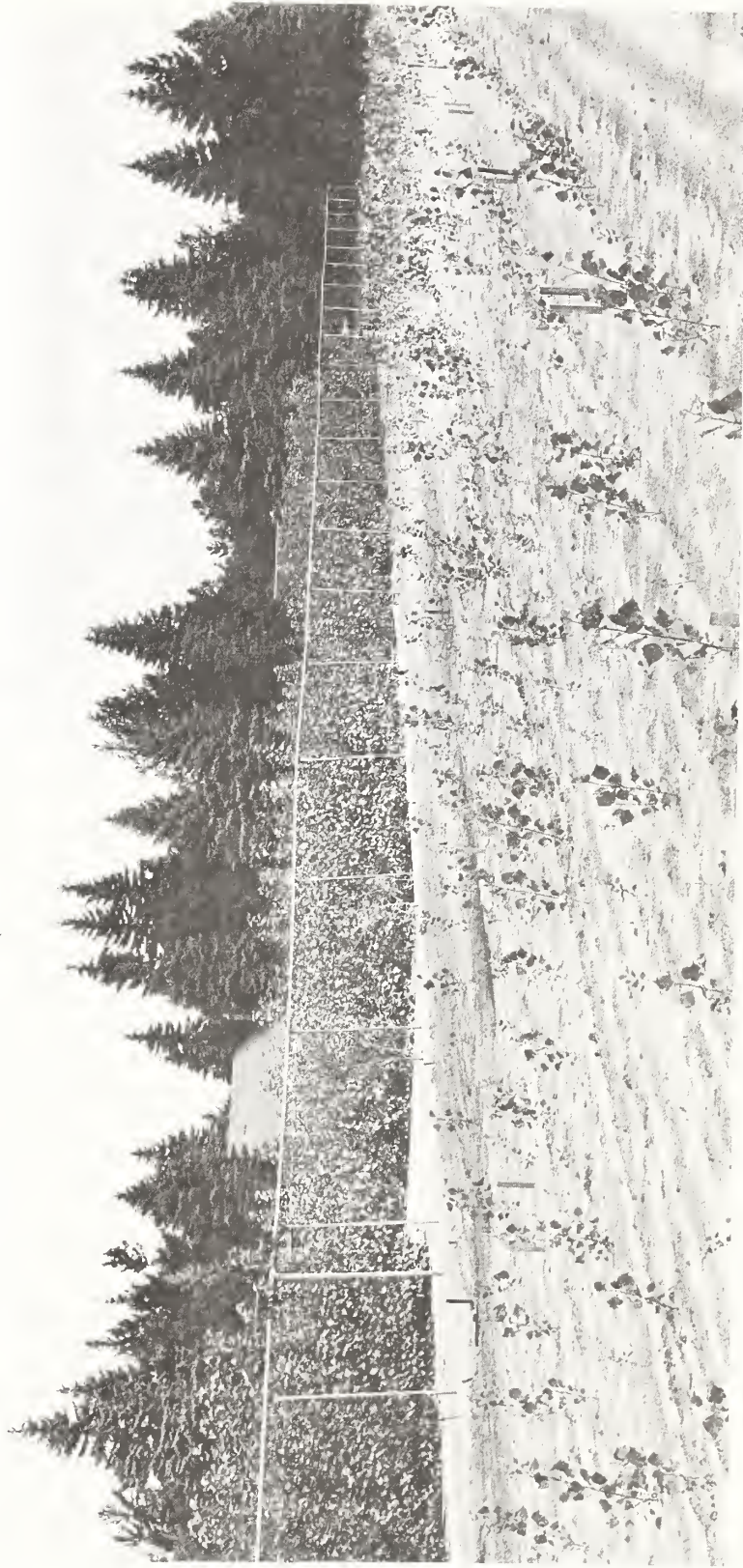


## Fast Growing Hardwoods for Fiber and Energy

Demands for wood for fiber products and fuel are expected to more than double by the end of this century, and new methods for culturing trees will probably be required to meet these demands. Research results at the North Central Station indicate that yields of certain hardwood species can be increased severalfold by following some new cultural techniques.

Keys to success include selecting stock that has genetically superior growth rate and providing ideal conditions for rapid

tree development. In tests in Wisconsin, biomass yields (wood and bark in main stem and branches) have exceeded 8 tons per acre per year. Hybrids of *Populus* (genus that includes poplars, aspens, and cottonwoods) achieved these yields. Spacing of trees in the plantation and age at which trees are harvested are key factors in the system. Best projected yields with one test hybrid were from a 4-foot spacing and tree harvesting after 15 years. During the last year, the North Central Station published a summary of its findings on intensive culture of plantations.



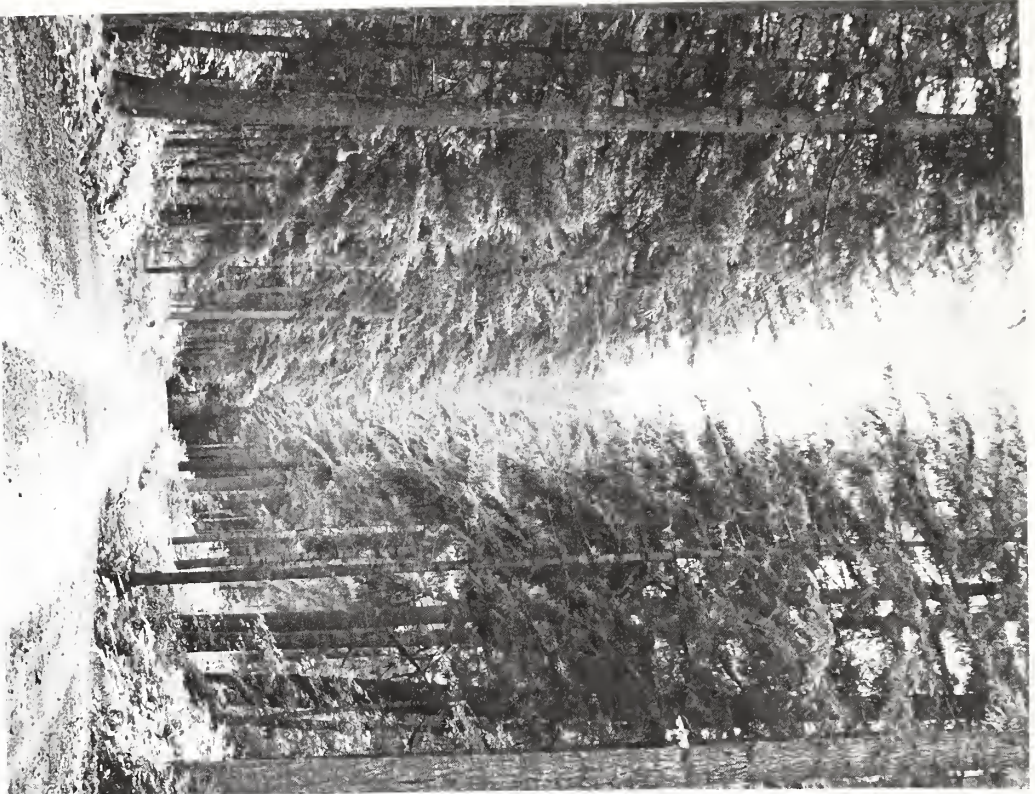
In experimental plantings, hybrids of *Populus* have yielded more than 8 tons per acre per year when ideal conditions were provided.



## Computer Gives Better Yield Predictions for Douglas-fir

In the Pacific Northwest, Douglas-fir has naturally seeded onto millions of acres after logging, and foresters need information on the best ways to manage these second-growth stands. How often should they be thinned? What volumes can be expected from thinning? Is fertilizer application worthwhile? How will such treatments affect tree size in the final harvest? The Pacific Northwest Station has done a great deal of research on these questions. The answers, of course, depend upon the quality of the site on which a stand is growing. Results of numerous spacing, thinning, and fertilization studies have now been synthesized. Yields from thinning and final harvests of Douglas-fir stands can be predicted with the aid of a computer.

This yield simulator, as it is called, is already being used by the National Forests in the Pacific Northwest as well as by Federal and State agencies and forest industries. The Pacific Northwest Station has prepared a user's guide to the simulator. It tells what sorts of information must be supplied and exactly what kinds of answers will be provided. Results are applicable in the Coast Range and in the Cascades up to elevations of about 2,500 feet. The entire program is available to those who want it, but most will probably prefer to supply information in the proper form and get their answers from a Forest Service computer.



Douglas-fir occupies millions of acres of cutover land on the West Coast. A computer program helps to get the most from these second-growth stands.

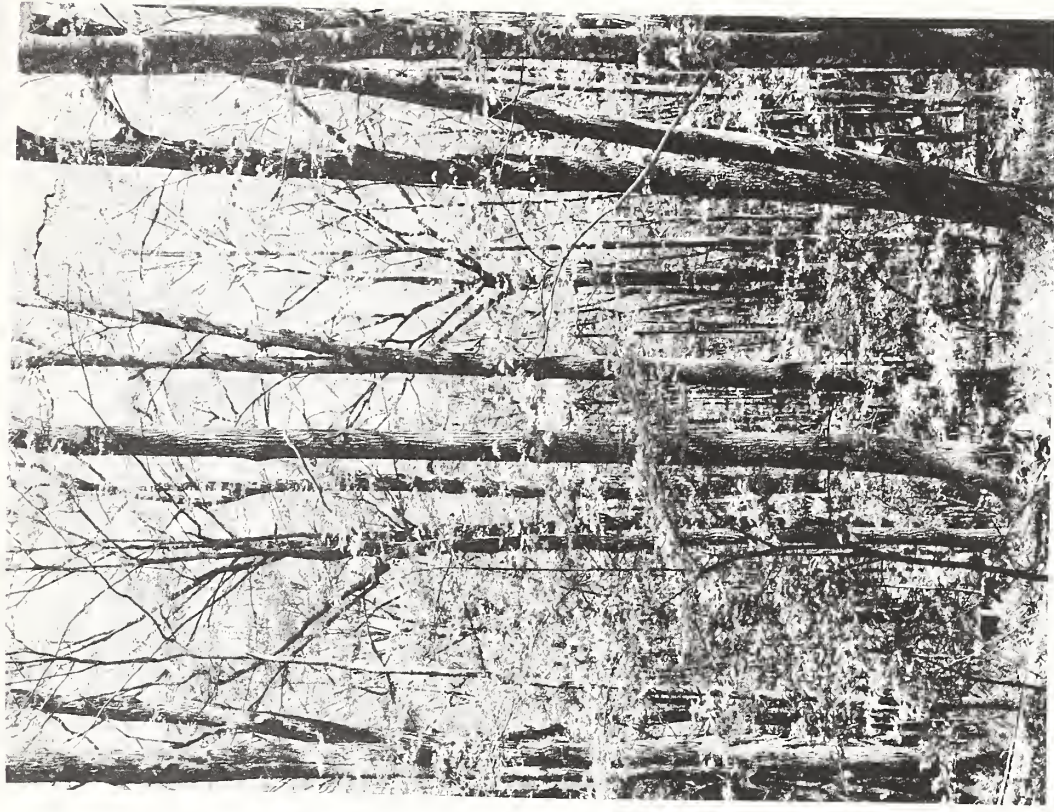


## Improving Multiple Use Management

Forests produce timber, water, habitat for a wide variety of wildlife, forage for livestock, and recreation opportunities. Harmonizing management actions to produce an ideal combination of these benefits has always been difficult and complex, particularly on public lands. For one thing, actions that benefit one species of wildlife may create adverse conditions for another species. Before major management decisions are made on National Forests, alternative courses of action and their effects upon benefit production are presented for public comment. A way has long been needed to quickly determine the effects of many timber management alternatives on production of other benefits.

A scientist at the Southeastern Station has devised a system for doing just that. The system, which makes heavy use of a computer, displays the effects of changes in timber-cutting schedules on production of other benefits and adverse effects. Benefits and adverse effects are assumed to be directly related to the proportions of the forest in various age classes and to the sizes of openings made in timber harvests. The exact relationships must be specified by the manager, but he can draw on a great deal of research and experience in doing so. Once the relationships have been mathematically described, the computer will display benefits and adverse impacts for any of a multitude of management alternatives that lead to a stable distribution of stand age classes within a forest.

The system has been fully programmed and demonstrated for a mixed hardwood watershed in the southern Appalachians, but it can be applied to any forest situation. A publication describing the system and the computer program, called DYNAST, is available from the Southeastern Station.



New management system has been demonstrated on upland oak stands in the Southeast, but it can be applied throughout the country.

## Containerized Seedlings Aid Reforestation

About 3 million acres of southern pine must be reforested each year if predicted demands for stumpage in the year 2,000 are to be met. Currently, less than half of that goal is being met, but research studies and pilot tests by the Southern Station indicate that containerized seedlings will help in the needed reforestation efforts.

The traditional method of planting is to lift seedlings from nursery beds and plant the bare-rooted stock in the field. Seedlings must be dormant for this method to succeed. A containerized seedling is grown in the nursery in a small, low-cost container that holds both the seedling and its soil. The seedling is outplanted in its container, which breaks down as the seedling develops. One advantage of the containers is that they are highly adaptable to mechanized planting. Another is that they improve nursery survival. But perhaps the most important advantage is that they permit an extension of the planting season, which is all too brief for the big job that is required.

The research findings are now being applied on several National Forests, and State and private organizations are considering their use. Containerized seedlings may not be the entire answer to shortfalls in reforestation, but they certainly should help.

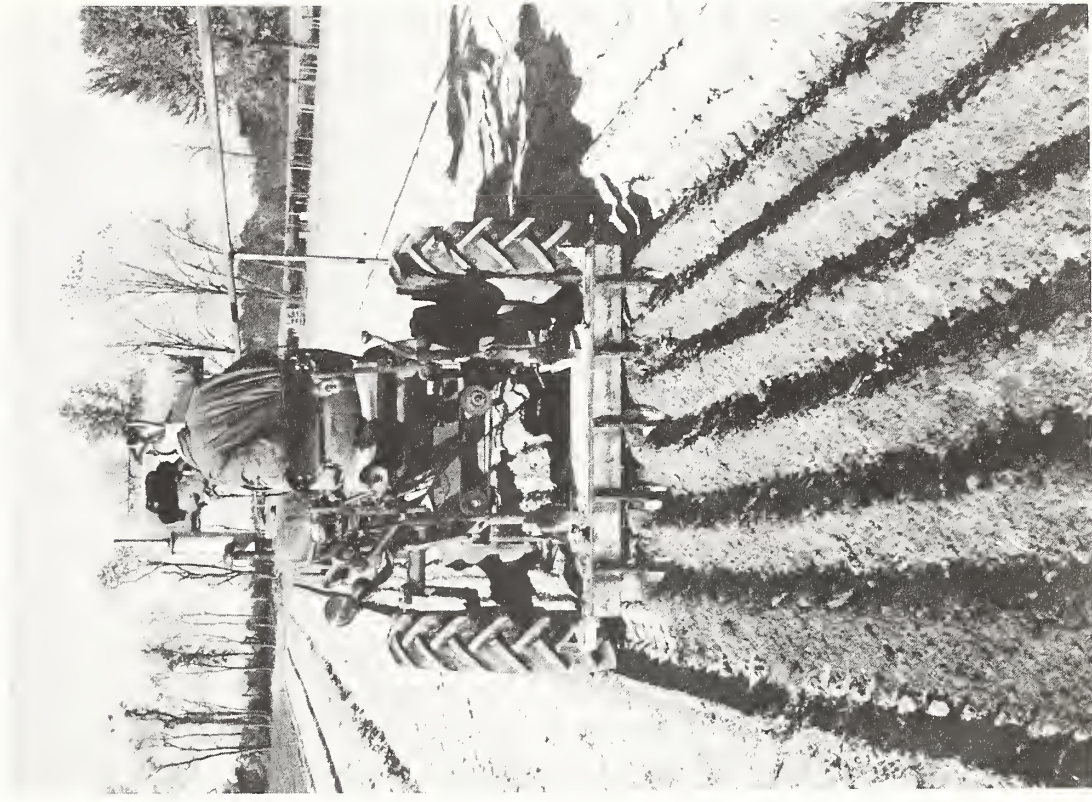




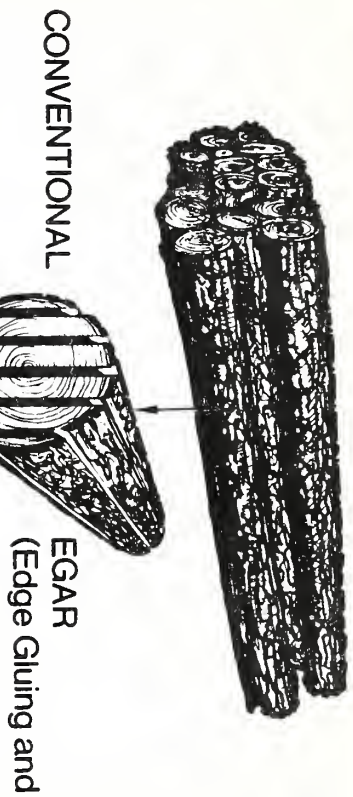
## Guidelines for Hardwood Nurseries

After years of planting only conifers, foresters in the Eastern United States have become interested in planting hardwoods on the sites where they outperform conifers. Very few forest nurserymen, however, are proficient in raising hardwood seedlings. The nursery practices developed for conifers often do not work with hardwoods. Furthermore, there are so many hardwood species, each with special nursery requirements. Scientists at the North Central Station found that much of the information that nurserymen needed had been published, but in widely scattered research reports.

To solve this problem, they gathered all the available information and published an illustrated guide for hardwood nurserymen. The guide covers a wide range of topics, including management of soil; collection, extraction, testing, and sowing of seeds; and protection, care, inventory, packing, and shipping of seedlings. The book should help nurserymen in the eastern half of the United States to meet rapidly increasing demands for high-quality hardwood seedlings.



## More and Better Lumber from Small Logs



CONVENTIONAL

EGAR  
(Edge Gluing and  
Ripping)

Approximately 20 billion board feet of softwood dimension lumber are produced each year in the United States by methods that waste wood. Much of this waste results from removing the edges of pieces to produce lumber of standard width. Also, the width of the lumber produced is restricted by the size of the log from which it came. Researchers at the Forest Products Laboratory have found a way to get around this limitation and eliminate much waste.

In their system, small logs are sawn into boards of maximum width. The edges of these boards are trimmed and the boards are fused together edgewise, with waterproof glue. The flat panels produced by gluing are then ripped into lumber of the desired width.

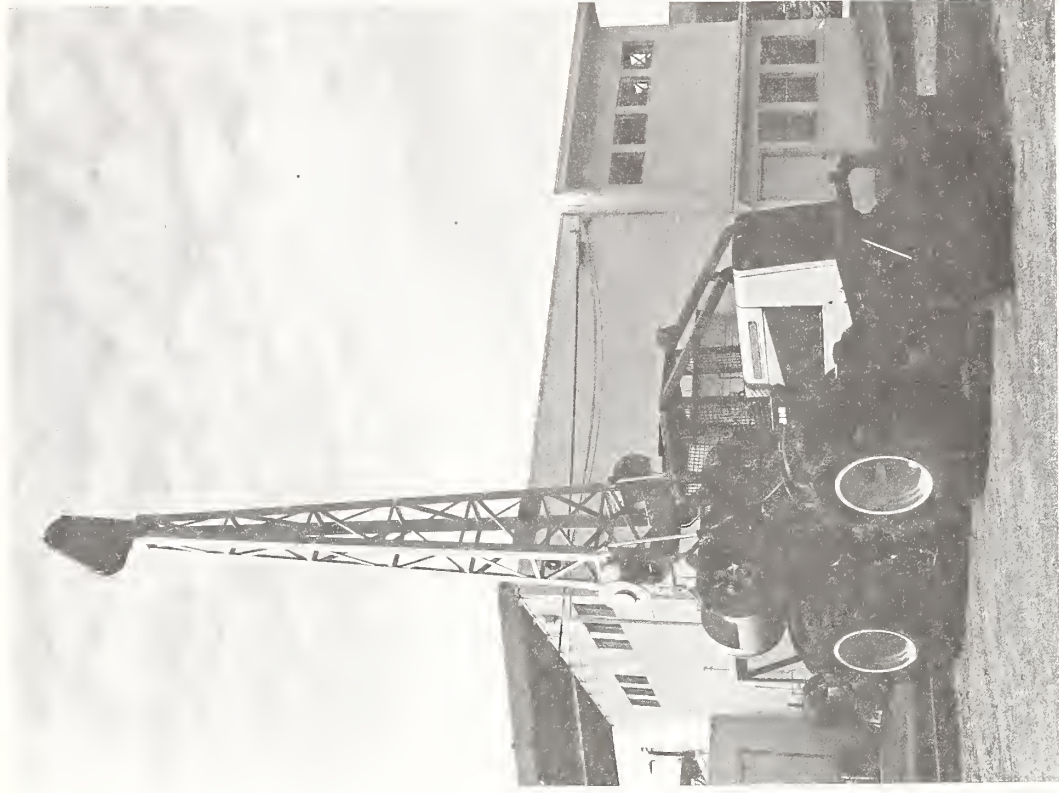
With this system, lumber of any width can be produced from small trees. Furthermore, test runs show that the lumber produced is stronger, and that yields from logs are increased by about 10 percent.

## A Machine for Mountain Logging

Mountain loggers in the Eastern and Western United States have long needed a machine that would remove logs from young stands on steep slopes without damaging the soil or the uncut trees. In the absence of such a machine, foresters have been unable to prescribe thinnings that they knew were needed. Working closely with private industry, engineers at the Pacific Northwest Station have come up with a solution. They call it the peewee yarder.

This machine was designed to handle small logs efficiently and quickly. It uses a skyline system that lifts logs off the ground, eliminating soil damage. Major innovations in the design of the drum drive permit line speeds of up to 750 feet per minute. High speed is necessary if movement of small logs is to be economical.

A prototype has been assembled and is being tested in the field. Use of the peewee should greatly improve timber culture on steep slopes.





## Douglas-fir Tussock Moth

In recent years one of the most damaging forest insects in America has been the Douglas-fir tussock moth. The Forest Service has joined with three other agencies in the U.S. Department of Agriculture, many universities, several States, and forest industries in a coordinated research program. The objective is to find environmentally sound ways to minimize damage by this insect. Major progress has been made.

Methods have been developed for predicting the severity of tussock moth outbreaks. Such information is extremely valuable to forest managers, who wish to know whether control efforts are needed or whether they are economically justified. Estimates can be made of the amount of defoliation, tree mortality, growth reduction, and topkill that can be expected without control and with standard treatments.

The sex attractant released by female moths to attract males has been synthesized in a laboratory. It has proved extremely attractive to males. When this material, which entomologists call a pheromone, is formulated for slow release and deployed in sticky traps, the presence of tussock moths can be detected where populations are too low for detection by previous methods.



A virus greatly magnified by an electron microscope.

Several chemical controls have been tested for effectiveness and environmental safety. One insecticide, is now registered for aerial application on tussock moth infestations, and another has been submitted for registration by the Environmental Protection Agency. Both of these chemicals present little hazard to small mammals, insect-eating birds, fish, and aquatic organisms.

Probably the safest control substance found so far, however, is not a chemical insecticide at all. It is a naturally occurring polyhedrosis virus (NPV), and it was registered for use against the Douglas-fir tussock moth in 1976. This is the first time that a virus has been registered for use against a forest insect, and is the culmination of 13 years of research and development at the Pacific Northwest Station. This work included isolation, identification, and description of the virus, development of insect-rearing and virus production methods, safety testing, formulation of a virus spray, and development of application methods. The virus is highly specific—it damages only the target insect. Tests with mammals, fish, birds, and other insects have shown no adverse effects.



Virus kills a high percentage of tussock moth larvae.





Hardwoods in winter? No, hardwoods in July! Gypsy moths have completely defoliated them. This insect (below) is a major pest in cities as well as rural areas.



## Gypsy Moth

One of the most promising developments in gypsy moth control is also a virus. It reduces moth populations and protects foliage quite well. Registration of this virus by the EPA for use against the gypsy moth has been applied for, and research on its value, safety, and use is continuing.

An insecticide is also under close study. Very small amounts of this chemical (0.03 to 0.06 pounds per acre) have been shown to inhibit molting of gypsy moth larvae. Tests are now underway to determine whether even smaller amounts may be effective. Multiple applications of the chemical may eradicate infestations in remote areas. This insecticide is unique in its mode of action, selectivity, and high toxicity to certain insect species at low dosages. These characteristics appear to make it unusually safe to use.

Effective controls of this insect will be welcomed by people throughout the Northeast. It is a major pest in cities and suburbs as well as in rural areas.



## Raising Timber and Elk

Elk are a favorite big-game species in the Rocky Mountains, and foresters want to favor them in their timber management prescriptions. They also want to disturb the animals as little as possible during timber harvesting. A scientist at the Rocky Mountain Station is supplying the information needed to harmoniously produce timber and elk.

Animal behavior has been closely followed in the research by tracking, direct observation, radio telemetry, and time-lapse photography. In radio telemetry an animal is captured and a small transmitter is attached to it. Then the movements of the animal can be observed at long range without disturbing it.

The research has shown what types of habitat the animals require. It has also shown that elk prefer to keep at least half a mile away from working loggers. Traffic on roads has less effect—animals commonly approach to within a quarter of a mile of well-used roads. Foresters are using such information in planning logging operations. State game commissions are using the information to determine quotas of animals that should be harvested to keep populations within the carrying capacity of the land.



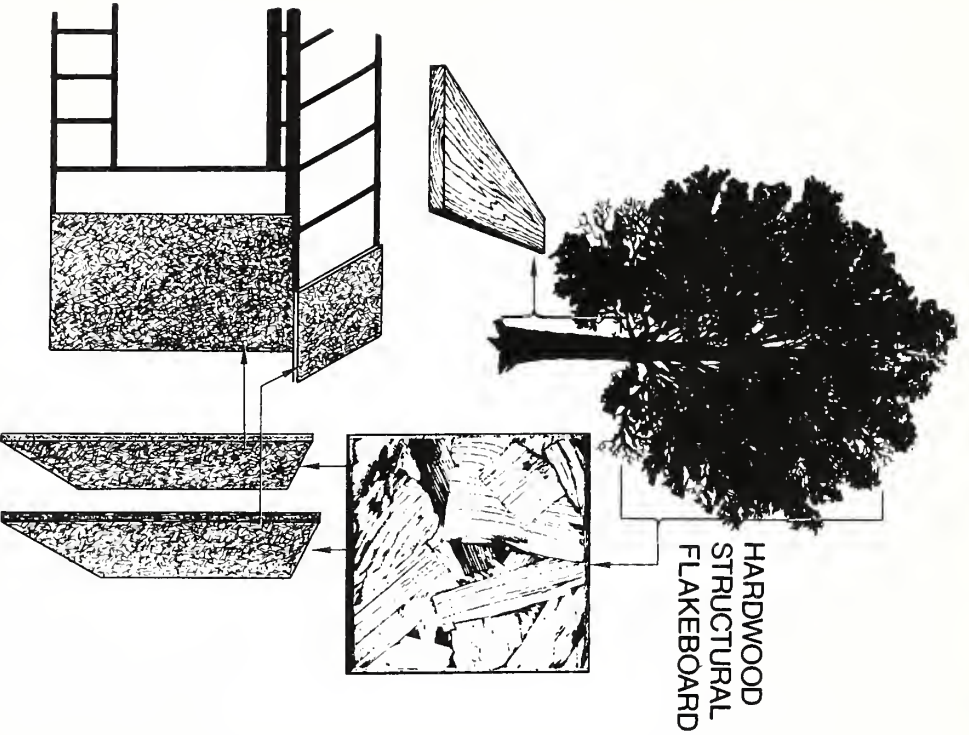
By attaching radio transmitters to captured animals and releasing them, scientists have been able to observe the effects of disturbances, such as logging, on animal behavior.

# Finding Uses for Small Hardwood Trees

Huge volumes of potentially usable hardwoods in the Eastern and Southern United States are considered unmerchantable. One major goal of Forest Service research is to find profitable uses for these trees. Flakeboard and furniture are two good possibilities.

Scientists at the Forest Products Laboratory and at Purdue University think that small and poor-quality hardwood trees might be converted into flakeboard for roof decking. Tests on small samples of the flakeboard have met the engineering requirements for roof decking. In addition, this decking appears to have better insulating qualities than some traditional materials. The flakeboard manufacturing process is highly efficient, and most of the energy required for processing could be produced by burning bark and panel trimmings.

Researchers at the Northeastern and Southeastern Stations believe that satisfactory lumber for furniture can be made from small hardwood trees of medium quality in a method that they developed and called "System 6." Such tree stems are bucked into 6-foot bolts rather than the longer logs that are traditional. Since large, high-quality hardwoods are in very short supply, the furniture industry is showing considerable interest in System 6.

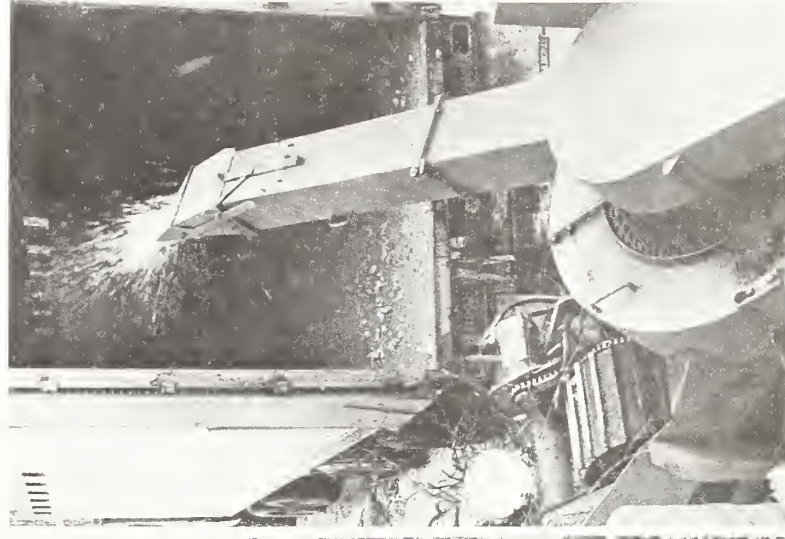
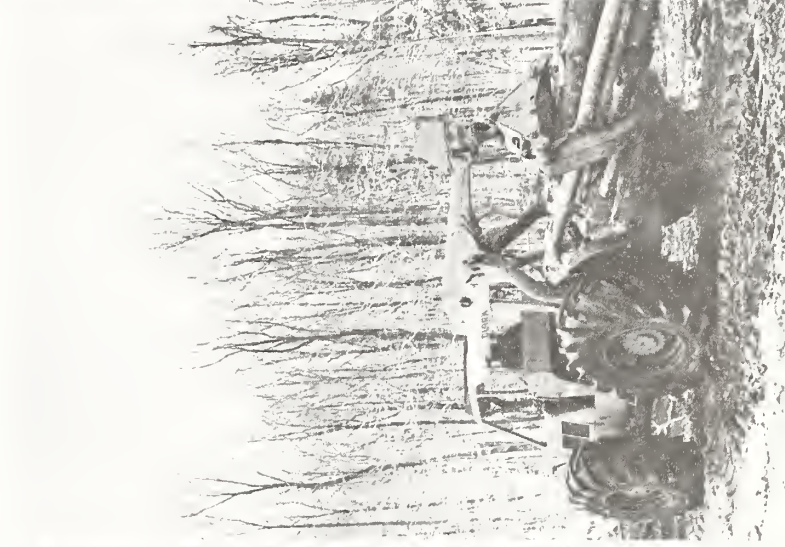
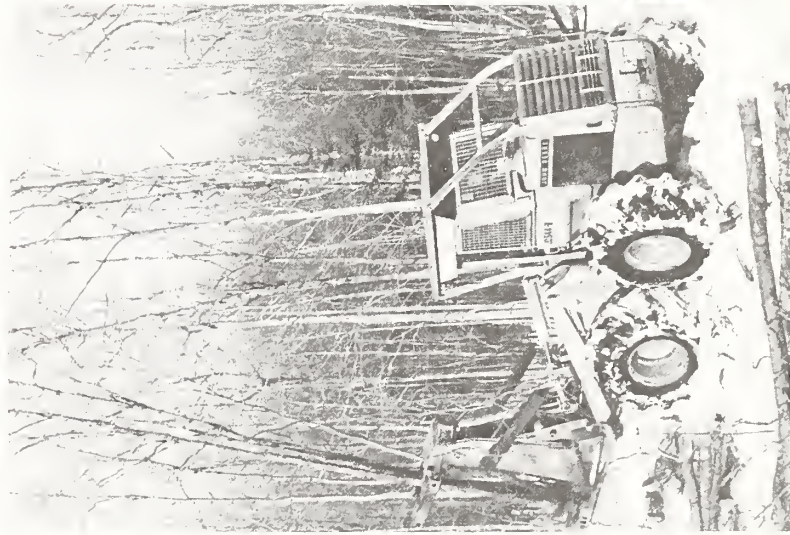




## Mechanized Thinning

Millions of acres of young hardwood forest in the eastern half of the United States would benefit from thinning, but there are few markets for the small trees that would be cut. One of the most promising markets is for fuel, probably for industries, but thinning procedures used in the past have not been efficient enough to deliver the wood at a competitive price. Engineers at the North Central Station believe that wood can be competitive if thinning is highly mechanized and highly efficient.

A system that the engineers have been testing appears promising. In rows 10 feet wide, all the trees are mechanically sheared by a large machine that places them in bunches. These bunches are hauled to a landing with a grapple skidder. At the landing, the logs suitable for lumber manufacturing are taken and the remaining material is chipped and blown into vans. These chips might be profitably hauled to nearby industrial plants as fuel. Studies of costs and returns are underway.





## New House Design Cuts Building Costs

The cost of new homes has been rising rapidly, and increases in lumber prices are a contributing factor. An engineer at the Forest Products Laboratory has invented a new frame design that can save both money and lumber. It is called a truss-frame. Both the floors and the roof rafters are trussed (see photo).

Advantages of the system are less framing lumber per square foot of house, use of only one size of framing lumber

(2x4's), and elimination of ductwork for heating and cooling. Preliminary estimates are that at least \$2,300 will be saved by using this design instead of the conventional one.

The inventor obtained a public patent on the system early in 1977. Since he is a Forest Service employee, this patent permits any firm to use the system without paying royalties. Existing truss plants and wood manufacturing firms have everything necessary to mass produce truss-frames throughout the United States.



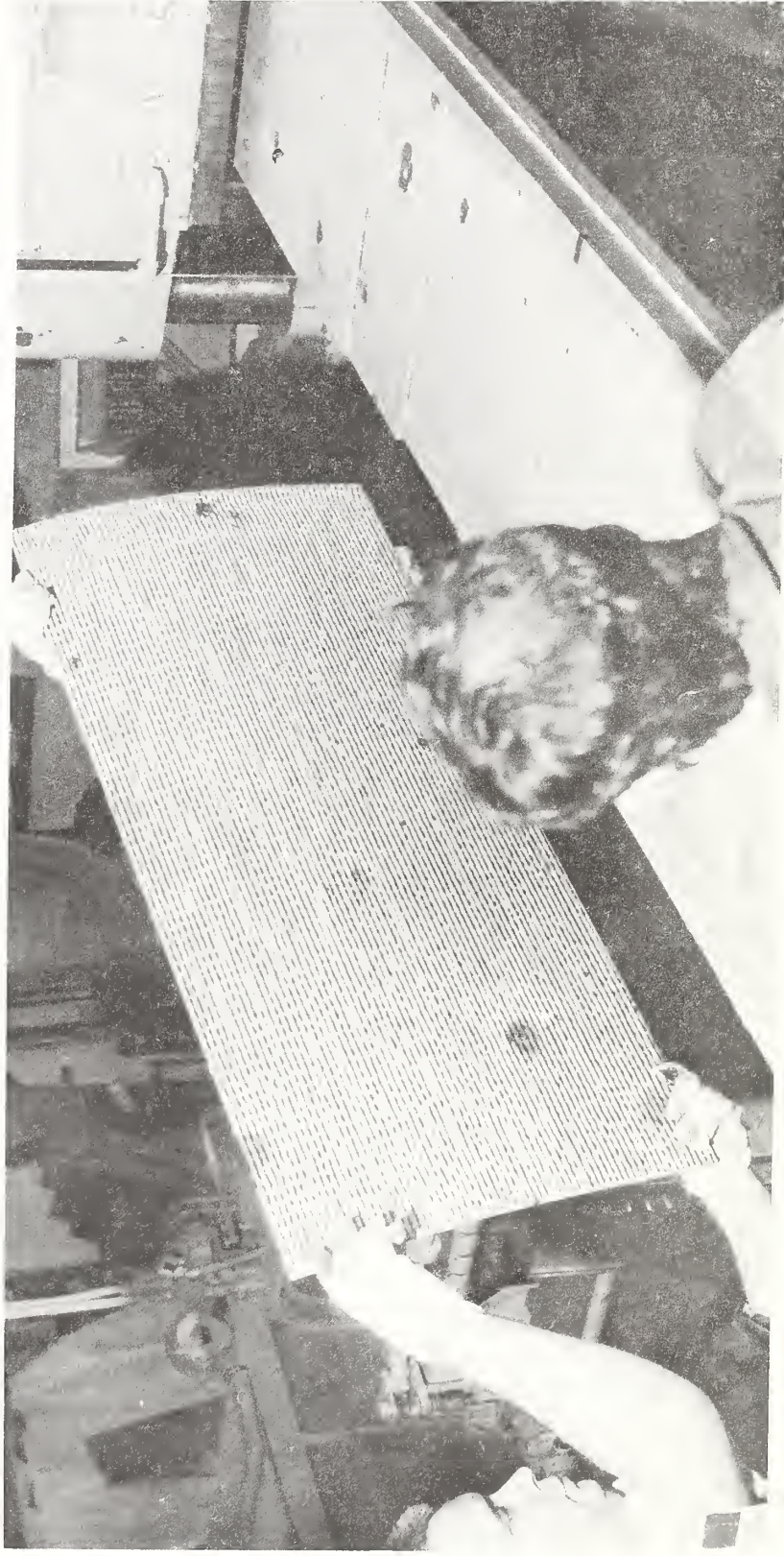
## Large Timber From Small Trees

Researchers at the Forest Products Laboratory have perfected a method for rapidly producing large structural timbers from small trees. And the process uses 30 percent less wood than traditional methods. The speed of the system is particularly beneficial because manufacturers will not have to hold materials for long periods while they dry.

The new product is called Press-Lam. Logs are peeled on a lathe into veneer up to one-half of an inch thick. The veneer

is cut into smaller sheets and put into a press where heat and pressure combine to dry the wood quickly. The dried sheets are coated with glue while they are still hot and laminated to the desired thickness. This means that manufacturers can make timbers much larger than the trees that provided the wood. And producers can go from log to dried, ready-to-use product in less than 1 hour.

Since the logs are peeled on a lathe rather than sawn, there are no losses in sawdust or slabs and edgings. This is why 30 percent more product can be made from a tree.



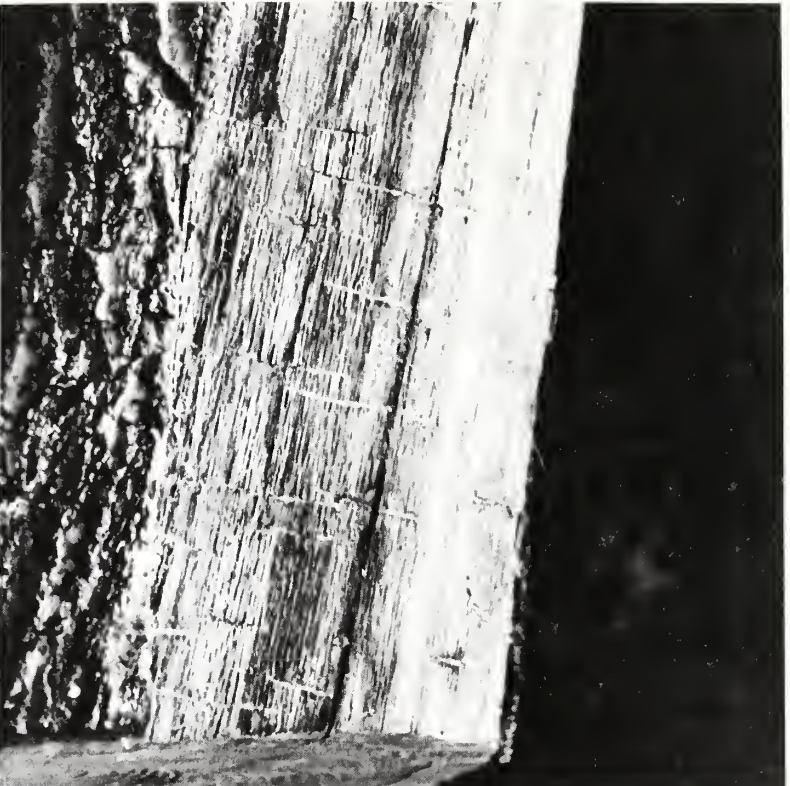


## Stopping the Spread of Oak Wilt

When a forest tree gets oak wilt, its chances of survival are low, so foresters would like to keep the disease from spreading to neighboring oaks. In hopes of protecting healthy trees, foresters used to girdle diseased oaks, but this treatment proved ineffective. Researchers at the Northeastern Station have discovered a treatment that does help to check the spread of oak wilt.

They found that when the herbicide cacodylic acid was injected into diseased trees under pressure, the likelihood of spread was greatly reduced. The herbicide kills the diseased tree and it kills neighboring oaks with interconnected roots, but these trees would die of the disease anyway.

Data on treatment effects have been submitted to a manufacturer who is applying to EPA for registration of the treatment.





## A Good Fungus

We often think of fungi as harmful organisms—causes of diseases—but many are highly beneficial, and scientists at the Southeastern Station are learning how to take best advantage of some beneficial ones.

Certain soil fungi form beneficial associations called mycorrhizae with the roots of higher plants. In fact, many higher plants require these associations for survival and normal growth. The fungi aid in uptake of nutrients from the soil, and may perform other useful functions.

Research is underway to determine the best mycorrhizal fungi for various tree species and soil conditions. Tests show that when nursery beds are inoculated with *Pisolithus tinctorius*, southern pine seedlings on the beds are healthier, grow faster, and require less fertilizer than seedlings on untreated beds. There are also indications that seedlings from inoculated beds will grow considerably faster after outplanting. Methods for commercial production of this fungus are now being tested in cooperation with private manufacturers.



Why are seedlings in background outperforming those in foreground? The soil in which they are growing contains a mycorrhizal fungus that sweetgum requires for normal development.

## Improvement of Deer Habitat in the South

Nutritional deficiencies in food limit the potential of southern pine forests for deer. Studies at the Southern Station show that these deficiencies can be partially compensated for by providing plots of high-quality forage. On such plots in Arkansas, deer consumed sizable quantities of elbon rye and ladino clover during the winter when acorns were scarce and when native forages were deficient in protein and phosphorus. Small clearings were grazed more heavily than large clearings. Yields and crude protein content of honeysuckle leaves were substantially increased by nitrogen fertilization. In Texas, burning increased the crude protein content of honeysuckle on unfertilized plots. These results indicate that supplementing native winter vegetation for cultivated forages in small plots should increase winter survival of deer in southern forests.

This information is being used by the Arkansas Game and Fish Commission to establish food plots on National Forests and State game management areas. Similar plots are being established on forest industry lands in Texas.





## Southern Pine Beetle

The southern pine beetle is extremely destructive during major outbreaks, which are somewhat widely spaced in most of the South. Artificial control measures are difficult to devise because the insect spends most of its life in the inner bark of trees, where it cannot be seen or treated. That is why much of the research on the insect is concentrating on silvicultural methods of population suppression and understanding natural control factors.

The major pathogens (causes of beetle diseases) have been determined in several Southeastern States. Although one pathogen may infect over 90 percent of the beetles, together the pathogens reduce populations by about 22 percent.

Studies of insect parasites and predators show that their densities increase as beetle populations increase. Woodpeckers appear to be particularly effective, consuming up to 80 percent of the beetles in some trees.

Developing an understanding of the site and stand conditions which favor chronic beetle outbreaks will help in devising stand or forest management practices that may reduce susceptibility to the insect. Research has shown that infestations are correlated with stands having high density of large, often overmature trees. Researchers hope to develop an array of information into a stand risk-rating system to help forest managers make decisions concerning stand treatment.

Another possible cause of increased susceptibility to southern pine beetle is a tree pathogen, *Fomitopsis annosa*, which attacks loblolly pine roots and has been found associated with beetle-infested loblolly pines. Scientists think this fungus may be predisposing trees to beetle attacks.



Woodpeckers are efficient predators of southern pine beetles, and insects help too. Clerid larva (left) is about to consume southern pine beetle larva in inner bark.



## Habitat for Endangered Species

The Forest Service tries to take no action that will harm an endangered species, and when enough is known about the habitat requirements of such a species, ideal conditions are provided for it. Determining habitat requirements is often difficult; the results with the red-cockaded woodpecker at the Southeastern Station show what can be done.

The red-cockaded woodpecker exists in scattered but apparently viable populations throughout the range of southern pines. It is listed as endangered because its nesting habitat—stands of old-growth southern pine—has steadily diminished as timber management has been intensified and rotations have been shortened.

Studies have shown that clans range over areas as large as 555 acres and defend territories as large as 205 acres. Within their territories, the woodpeckers utilize a wide range of stand ages and conditions. They eat many species of insects and spiders.

This information is being used by National Forests in the South to revise habitat management guidelines. The same information has been used by the Endangered Species Recovery Team of the U.S. Department of the Interior, Fish and Wildlife Service, to develop a recovery plan for the species.

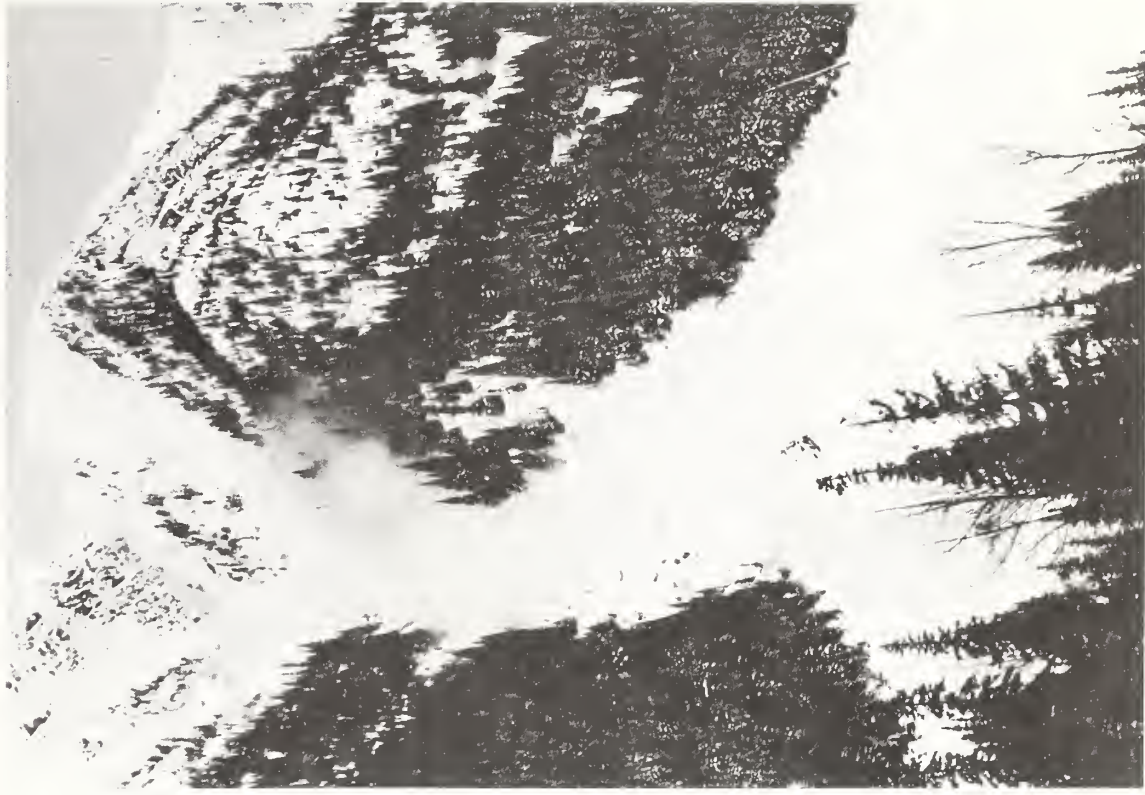


Habitat requirements for the red-cockaded woodpecker have been determined, and appropriate habitats are being provided on National Forests.

## Avoiding Avalanche Disasters

The number of winter residents in the Rocky Mountains is increasing rapidly, and in many locations the risk of snow avalanches is very real. The situation is so serious that the State of Colorado has a regulation designating avalanche sites as "areas of State concern." The objective, of course, is to recognize areas of high hazard and to allow only those uses that are compatible with the hazard. This should be done before extensive development takes place and land values soar.

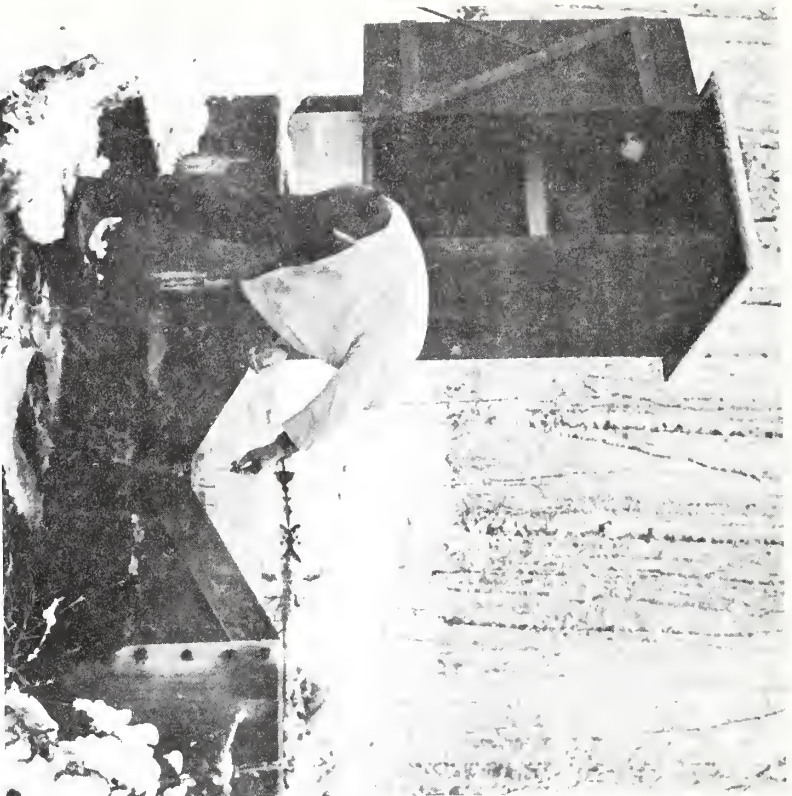
Scientists at the Rocky Mountain Station have produced an avalanche prediction model that should make such an approach possible. The model, which works on a computer, predicts the likelihood of an avalanche in a mountainous area when it is given easily obtainable information about the area. It also estimates runout distance and impact force for probable avalanches. Such information will help avert disastrous loss of life and property in the future.



## Nonpoint Pollution

Public Law 92-500 holds foresters accountable for water pollution arising from the areas under their management. Since the sources of such pollution are usually large treated areas or roads rather than specific points, they are called nonpoint sources. To assist land managers, Forest Service Experiment Stations all over the country are determining the effects of forest practices on water quality. Research to date pinpoints sediment as by far the most common pollutant. Logging practices and road designs that will aid in reducing sediment production are known, especially for most forest areas in Eastern United States. However, further research is needed.

Erosion in well-managed forests in the central Appalachians ordinarily ranges from 0.05 to 0.10 ton per acre per year. About half this material is sediment and the other half is dissolved minerals. This rate may double during a well-managed logging operation, but it returns to prelogging levels a year or two afterward. Increases in sediment production from careless logging, however, can be far higher and can last much longer.

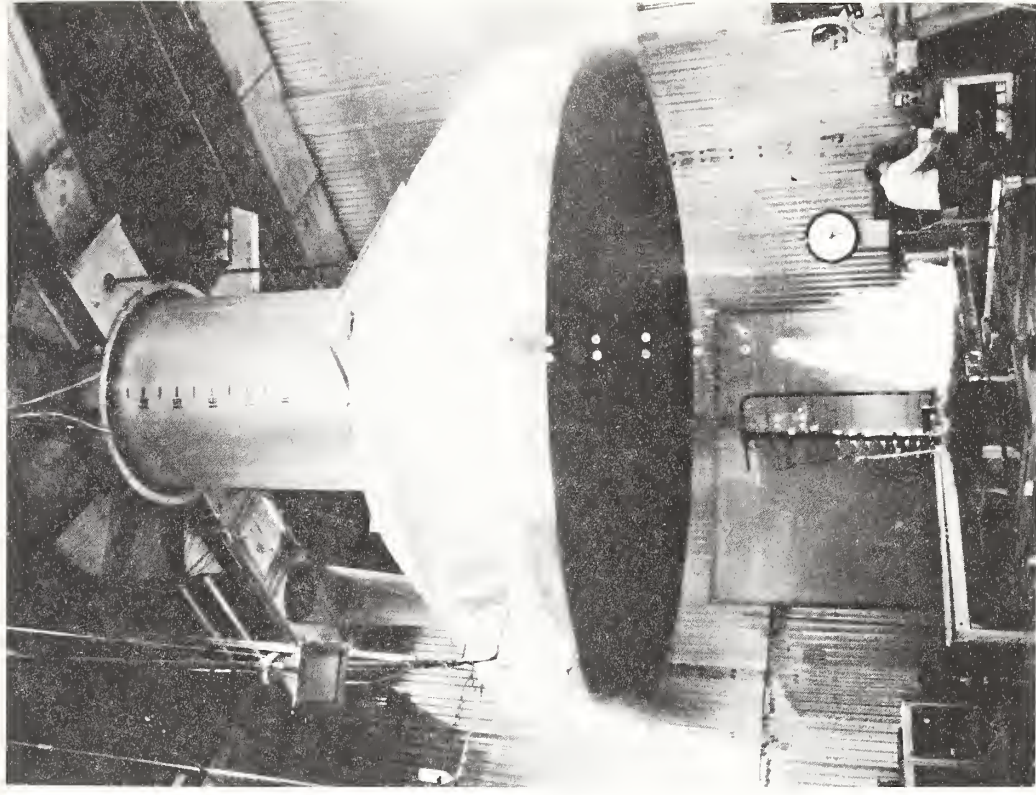


Forest Service scientists throughout the country are measuring effects of road building and forest treatments on water yield and quality.



## Smoke Management

Prescribed burning is often the most practical way to prepare a site for reforestation or to eliminate concentrations of fuel that would cause major damage in a wildfire. But burning at the wrong time or place can create unacceptable concentrations of smoke over populated areas or highways. The Southeastern Station has published a forestry smoke management guidebook to help southern land managers and air-quality personnel decide when prescribed burning is acceptable. With the guidebook, a user can predict probable concentrations of particulate matter for up to 100 kilometers downwind from fires. Since these computations can be quite complex, especially if several fires are being planned for in the same general area, a computer program has been developed to help land managers. Weather strongly influences the rate at which a fire burns and the manner in which the smoke disperses. The program for calculating rates of dispersion, therefore, has been combined with automated weather interpretation, and the combined system is being pilot tested in cooperation with the National Weather Service and operational forestry organizations.



In a laboratory, all combustion products from experimental burns are analyzed. In this way, the amounts of kinds of such products can be estimated for field burns.

## Estimating Residue Volumes

The unmerchantable wood that is left in the forest after timber harvesting or cultural treatment often creates a fire hazard and can hamper reforestation efforts. Methods have been developed for getting rid of these unwanted residues, but to apply these methods a forester must first estimate how

much material is present or will be created by a specific operation. The Pacific Northwest Station has perfected a rapid method for making these estimates.

The Station has published photographs for major softwood types in the region showing various fuel loadings. By comparing local conditions with those shown in the photographs, a manager can quickly estimate the volume present.



A method has been developed for quickly estimating logging residue volumes.



## Managing Nongame Animals

In their wildlife management activities, foresters have traditionally favored game animals and given little attention to other wildlife species. The primary cause was a lack of knowledge, but that situation is changing rapidly. Forest Service Experiment Stations all over the country are rapidly accumulating and publishing information on nongame species.

The Pacific Northwest Station has completed some research on the effects of timber management activities on forest bird populations in the Blue Mountains of Oregon and Washington. Cavity nesting birds, particularly woodpeckers, are very sensitive to habitat alterations associated with timber harvesting. Studies show that the size, condition, and location of dead trees (snags) are critical to reproduction of cavity nesting birds. The findings have been incorporated into a simple management system that has been adopted by all Federal and State agencies in the Blue Mountains.

Similar research has been completed by scientists at the Rocky Mountain Station. In Arizona, changes in bird populations have been observed after harvest of mixed conifer forests.

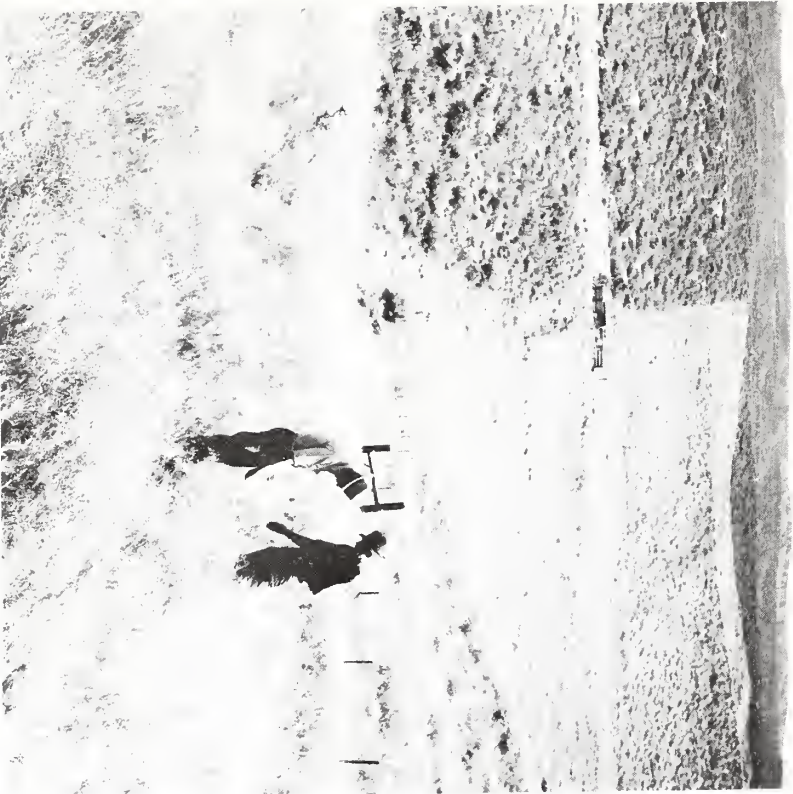




## Increasing Streamflow in Arizona

Water supplies for central Arizona are dwindling, but researchers at the Rocky Mountain Station think they have found a solution. They have found that chaparral with its deep roots uses considerably more water than shallow-rooted grasses and forbs. By converting areas of chaparral to grass both the volume and duration of streamflow can be increased. Conversion of about 700,000 acres of Arizona chaparral appears feasible, and such action would increase water yield by 140,000 acre-feet per year.

Some 1,300 acres of conversion are planned on National Forests in Arizona over the next year. Chaparral removal will be accomplished by machine and by prescribed burning. Effects of these treatments on water yield, wildlife, and range quality will be closely monitored.



Converting groundcover from chaparral (left) to grasses (right) can increase flows in Arizona streams.

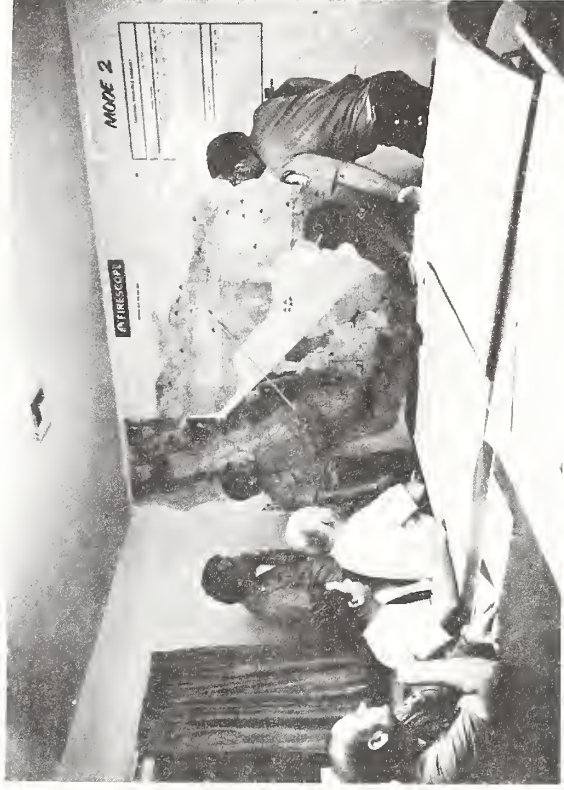
## Keeping a Computer Eye on Wild Land Blazes

Take 12 million people, put them into some of the most flammable forest lands in America, and you have southern California. Take a carefully planned command structure, mobilization plan, and communications system, put them together with the most advanced computer assistance, and you have FIRESCOPE, southern California's answer to its forest fire danger.

FIRESCOPE is a research, development, and applications program that was started to determine how men and equipment from many agencies and departments could best be used for large fires and other emergencies. Seven major organizations are participating with the Forest Service in the effort. They include Federal, State, and city agencies. All have worked out a standardized management structure and procedures to use when they are called upon to work together. There is common terminology and common understanding.

The core of the system is the Operations Coordination Center in Riverside, near the Pacific Southwest Station's Forest Fire Laboratory. There, a close eye is kept on potential fire hazards in seven surrounding counties. A vital part of this command center is a computer terminal on which the coordinates of all brush fires and up-to-the-minute weather data are entered. The computer already has stored in its memory details on the age and moisture content of the vegetation and the steepness of the slopes. In seconds, the computer forecasts how fast a fire will spread and in which directions. FIRESCOPE also takes advantage of infrared fire mapping of aircraft flying 10,000 to 15,000 feet above a fire. In this way, fire maps can be kept current at night and in spite of smoke. Much of the research needed to make the system work was completed at the Pacific Southwest Station.

FIRESCOPE is protecting 15 million acres in southern California, but the principles in use there have much broader application. With adaptation, the same concepts and technology could be applied in other areas where major emergencies make multiagency cooperation essential.



## Timber and Salmon

One of the great wonders of nature is the return of the coho salmon and other anadromous fish from the sea to the streams of their birth for spawning. Forest managers and ranchers need to know if any of their activities are interrupting this phenomenon, and researchers at the Pacific Northwest Station are providing the answers.

Streamside vegetation is very important to fish habitat for two reasons. It reduces stream temperatures and it reduces the amount of sediment reaching streams. The salmon spawns in streambed gravel, often laying its eggs as much as 12 inches below the surface of the gravel. If the gravel is clogged with sediment, sufficient oxygen may not reach the eggs and fry. Furthermore, the fry must work their way up through the gravel, and they find this very difficult when sediment is present.

Considerable research has been done in artificial streams where conditions can be carefully controlled. Results indicate that round gravel collects more sediment than angular gravel at low streamflow rates. At streamflows much over 1 foot per second, however, the round gravel appears to be preferable. This information will be helpful to those who are considering construction of artificial spawning areas.

The amounts of streamside disturbance that are acceptable have been studied carefully, and results of this work are being applied in National Forests in the Northwest and Alaska.



Treatment of streamside vegetation strongly affects salmon spawning. Here a Forest Service crew is removing fallen trees from an Alaskan stream.



## Classifying Forest Habitats

The Intermountain Station has devised an improved system for classifying forest habitats in Montana. Useful classification systems with standard treatments for members of each class provide a means for identifying the various forest habitats. Scientists at the Intermountain Station believe that one problem in forestry in the northern Rocky Mountains has been inadequate classification of forest conditions. They found that wildlife biologists had one classification system, forest managers another, and other resource specialists still others. As a result, people in different disciplines had trouble communicating with each other.

The solution was to devise a system based on the ecological principles of plant succession. The idea of succession is that on land with given characteristics vegetation will pass through predictable stages to a predictable climax in the absence of disturbance. In their Montana classification, the scientists recognized 64 habitat types and 37 additional phases of the habitat types. Understory as well as overstory plants are considered in the system. Distribution, vegetation, and soils are described for each type and a key is provided to determine what type is present on a particular tract. Some notes on management are also provided.

### Forested Scree

*Abies lasiocarpa*/*Menziesia ferruginea*

*Abies lasiocarpa*/*Vaccinium scoparium*

*Abies grandis*/*Clintonia uniflora*

*Picea*/*Clintonia uniflora*

*Tsuga heterophylla*/*Clintonia uniflora*

*Thuja plicata*/*Clintonia uniflora*

*Abies lasiocarpa*/*Xerophyllum tenax*

*Pinus flexilis*/*Agropyron spicatum*

*Pinus ponderosa*/*Prunus virginiana*

*Pinus albicaulis*-*Abies lasiocarpa*

*Pseudotsuga menziesii*/*Vaccinium caespitosum*

## All About Western Larch

Research discoveries about a tree species normally come one at a time, rather than in bunches. As a result, researchers usually write articles about single discoveries. Foresters, however, need single publications that contain all the latest information about managing a species. Such publications save them a lot of time and effort. The Intermountain Station has produced information that a forester needs to manage western larch. A 96-page publication contains recommendations, tables, and charts. Economic, biological, and environmental considerations are detailed. Methods for managing and reproducing the species are provided, along with estimates of growth and yield under various conditions. A bibliography is provided for research scientists and others who require details that were not included.





## Economic Options for Southeast Alaskan Timber

A large supply of timber is one of the major assets of southeastern Alaska, and Forest Service management policy has been oriented to strengthen employment and economic growth in the area through its use. Recently, however, the sufficiency of this objective has been questioned.

Alaskans are becoming increasingly concerned about preservation of esthetic values both for themselves and for a growing tourist industry. The economic climate is also changing. The world market for dissolving pulp has weakened. One pulp-firm plans to shift to a different product and another long-studied pulp-mill development has been scratched. A large saw-mill that produced dimension lumber has closed. The great distance to markets in the lower 48 States and restrictions on exports to Japan are major problems in marketing Alaskan timber.

Together, these conditions raise many questions for land managers and regional developers. To provide answers to these questions, a joint study was conducted by economists of the Pacific Northwest Station working with National Forest and State officials. Their report, which is still being reviewed by State and National officials, clarifies probable effects of timber management and sales options on employment and regional development, and provides an improved basis for developing long-term management strategies for southeastern Alaska.



Forest industries are an important source of employment, but Alaskans are concerned about preserving esthetic values both for themselves and for a growing tourist industry.





## Growing Up Without Forests

The urban child of today sees far less of forests and fields than did his counterpart one generation ago. Does this lack of experience with nature adversely affect a child? No one knows for sure. Effects on psychological development, self-concept, and preparation for responsible citizenship are very hard to isolate and measure, but a lot of people are thinking about these things.

The Northeastern Station held a symposium on the topic, gathering leading scientists who have done related research. Their thoughts are contained in 33 papers printed in the symposium proceedings. The papers summarize what is now known and indicate promising areas for research on this important problem.



## Managing Rivers for Recreation

Rivers are among our Nation's most valuable natural resources, and public concern about the best uses of rivers has been growing. Partly to aid in planning of future research, the North Central Station held a symposium of experts on river recreation, safety, and management. The papers presented at the meetings have been printed in a single publication, which is the best available summary of current knowledge about river management. It should be useful to various groups concerned with river recreation—planners and managers, public agency administrators, researchers, students, businessmen, members of recreation and conservation organizations, and private citizens.



## FOREST ENVIRONMENT RESEARCH

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